# Chapter 7
# Industry, Technology, and the Global Marketplace

## Contents

# Highlights

## International Economic Comparisons

- **The U.S. economy continues to rank as the world's largest, and Americans continue to enjoy one of the world's higher standards of living.** Japan's economy was less than 18 percent of the U.S. economy in 1960 and trailed several European economies. By 1970, it had grown to be the world's second largest economy, and in 1989, Japan had a gross domestic product (GDP) twice that of Germany and equal to nearly 40 percent of U.S. GDP. The latest data (through 1996) show a strong U.S. economy outperforming other advanced industrial countries since 1991.

- **Comparisons of general levels of labor productivity, measured by GDP per employed person, show other parts of the world increasing labor productivity faster than the United States.** For more than 40 years, labor productivity growth in the United States generally trailed that in other countries. As of 1996, the gap had closed significantly, with labor productivity rates in many European nations nearly equal to that achieved in the United States. In 1960, U.S. GDP per employed person was twice that calculated for most European nations and four times that calculated for Japan.

## U.S. Technology in the Marketplace

- **The United States continues to be the leading producer of high-technology products, and is responsible for about one-third of the world's production.** During the 1990s, U.S. high-technology industries regained some of the world market share lost during the previous decade. Its margin of leadership had narrowed during the 1980s when Japan rapidly enhanced its stature in high-technology fields.

- **The market competitiveness of individual U.S. high-technology industries varies, although each of the industries maintained strong—if not commanding—market positions over the 18-year period examined.** Three of the four science-based industries that form the high-technology group (computers, pharmaceuticals, and communications equipment) gained world market share in the 1990s. The aerospace industry was the only U.S. high-technology industry to lose market share from 1990 to 1997.

- **U.S. trade in technology products accounts for a larger share of U.S. exports than U.S. imports; it therefore makes a positive contribution to the U.S. overall balance of trade.** After several years in which the surplus generated by trade in technology products declined, this trend was reversed during the mid-1990s. Between 1990 and 1995, trade in aerospace technologies consistently produced large—albeit declining—trade surpluses for the United States. Since then, U.S. exports of aerospace technologies and electronics have outpaced imports leading to larger trade surpluses in 1996 and 1997 before narrowing in 1998.

- **The United States is also a net exporter of technological know-how sold as intellectual property.** Royalties and fees received from foreign firms have been, on average, three times those paid out to foreigners by U.S. firms for access to their technology. U.S. receipts from licensing of technological know-how to foreigners were about $3.3 billion in 1997, down slightly from $3.5 billion in 1996. Japan is the largest consumer of U.S. technology sold as intellectual property, and South Korea is a distant second. Together, Japan and South Korea accounted for 56 percent of total receipts in 1997.

## International Trends in Industrial R&D

- **Despite a two-decade decline in its international share of industrial research and development (R&D), the United States remains the world's leading performer of industrial R&D by a wide margin.** Data for 1995 and 1996 show a sharp increase in U.S. industrial R&D performance, outpacing growth in both Japan and the European Union. After 1990, the U.S. share stabilized at 46 percent of total industrial R&D performed by the Organisation for Economic Co-operation and Development (OECD) countries. By comparison, the European Union (EU) accounted for 30 percent of the total industrial R&D performed by OECD countries during 1990–94, and Japan accounted for about 20 percent.

- **Internationally comparable data on overall U.S. industrial R&D performance show the service sector's share rising from 4 percent in 1982 to 24 percent by 1992. During the period 1994–96, this sector's share of the total dropped to around 20 percent.** U.S. service sector industries, such as those developing computer software and providing communications services, have led the increase in R&D performance within the U.S. service sector. Service-sector R&D now accounts for a larger share of U.S. industrial R&D performance than either the electronics industry (13 percent of total) or the aerospace industry (11 percent of total)—the top two R&D-performing industries in the U.S. manufacturing sector in 1996.

## Patented Inventions

- **In 1998, nearly 148,000 patents were issued in the United States.** The record number of new patented inventions capped off what had been years of increases. U.S. inventors received 54 percent of the patents granted in 1998. Although the 1998 share represents a drop of 1 percent from the previous year, the proportion of new patents granted to U.S. inventors has generally risen since the late 1980s.

- **Foreign patenting in the United States continues to be highly concentrated by country of origin. In 1998, two countries—Japan and Germany—accounted for nearly 60 percent of U.S. foreign-origin U.S. patents.** The top four countries—Japan, Germany, France, and the United Kingdom—accounted for 70 percent. Both South Korea and Taiwan dramatically increased their U.S. patent activity in the late 1980s and, in 1998, were awarded more U.S. patents than Canada—historically one of the top five foreign inventors patenting in the United States.

- **Recent patent emphases by foreign inventors in the United States show widespread international focus on several commercially important technologies.** Japanese inventors tend to concentrate their U.S. patenting in consumer electronics, photography, and—more recently—computer technologies. German inventors continue to develop new products and processes in technology areas associated with heavy manufacturing industries, such as motor vehicles, printing, advanced materials, and manufacturing technologies. Inventors from South Korea and Taiwan are earning an increasing number of U.S. patents in communications and computer technologies.

- **Americans successfully patent their inventions around the world.** U.S. inventors received more patents than other foreign inventors in both neighboring countries (Canada and Mexico); but also in distant and diverse markets, such as Japan, France, Italy, Brazil, India, Malaysia, and Thailand.

## Venture Capital and High-Technology Enterprise

- **The pool of venture capital managed by venture capital firms grew dramatically during the 1980s as venture capital emerged as an important source of financing for small innovative firms.** Both investor interest and venture capital disbursements continued to grow through 1998. In the early 1990s, however, the venture capital industry experienced a "recession" of sorts as investor interest waned and the amount of venture capital disbursed declined. This slowdown was short-lived, however, and investor interest picked up in 1992, and disbursements began to rise.

- **Software companies attracted more venture capital than any other technology area.** In 1998, venture capital firms disbursed a total of $16.8 billion, of which more than one-third went to firms developing computer software or providing software services. Telecommunications companies were second with 17 percent.

- **Very little venture capital actually goes to the entrepreneur as "seed" money.** During the past 10 years, money given to prove a concept or for early product development never accounted for more than 6 percent of total venture capital disbursements and most often represented 2–4 percent of the annual totals. In 1998, seed money accounted for about 4 percent of all venture capital disbursements, while money for company expansion was about 56 percent.

## Following are some trends based on the various indicators of technology development and market competitiveness examined in this chapter:

- The United States continues to lead or be among the leaders in all major technology areas. Advancements in information technologies (computers and telecommunications products) continue to influence new technology development and to dominate technical exchanges between the United States and its trading partners.

- Asia's status as both a consumer and developer of high-technology products has been enhanced by the technological development taking place in the newly industrialized Asian economies—in particular, South Korea and Taiwan—and in emerging and transitioning economies, such as China, Malaysia, and the Philippines. Despite its current economic problems, Asia's influence in the marketplace seems likely to expand in the future as other technologically emerging Asian nations join Japan as both technology producers and consumers.

## Beyond these challenges, the rapid technological development taking place around the world also offers new opportunities for the U.S. science and technology (S&T) enterprise:

- For U.S. business, rising exports of high-technology products and services to expanding economies in Asia, Europe, and Latin America are already apparent in the U.S. trade data and should grow in the years ahead.

- For research, the same conditions that create new business opportunities—the growing global technological capacity, the relaxation of restrictions on international business—can lead to new opportunities for the U.S. S&T research community. The many new, well-funded institutes and technology-oriented universities surfacing in many technologically emerging areas of the world will further scientific and technological knowledge and lead to new collaborations between U.S. and foreign researchers.

# Introduction

## Chapter Background

Science and engineering (S&E), and the technological developments that emerge from S&E activities, enable high-wage nations like the United States to compete alongside low-wage countries in today's increasingly global marketplace. Nearly a universally accepted wisdom today, the importance of S&E activities to the Nation's economic well-being was emphasized 50 years ago in *Science and Public Policy*, a report prepared for then-President Harry S Truman under the guidance of John Steelman (1947). (See chapter 1.) It stated, "Only through research and more research can we provide the basis for an expanding economy, and continued high employment levels." In the years following World War II, U.S. industry became an integral part of the research enterprise. Not just as a performer of R&D, U.S. industry became the main conduit for diffusing and commercializing investments in S&T made by industry, academia, and government. The *Science and Engineering Indicators 2000* continues to acknowledge the important role played by industry. Contained within this chapter are indicators or proxies that identify trends and provide measurements of industry's part in the S&T enterprise and, whenever possible, place U.S. activity and standing in the more science-based industries in a global context.

The highly competitive global marketplace facing the Nation today is yet another condition predicted 50 years ago in the Steelman report. Steelman (1947) warned of the reemergence of war-torn economies in Europe and Asia and the emergence of a new cadre of nation traders that would "...confront us with competition from other national economies of a sort we have not hitherto had to meet." If a nation's competitiveness is judged by its ability to produce goods that find demand in the international marketplace while simultaneously maintaining—if not improving—the standard of living of its citizens (OECD 1996), then the United States appears to have met the challenges outlined in the Steelman report. Now some 50 years after that report was written, the U.S. economy ranks as the world's largest, and Americans enjoy one of the world's higher standards of living—although many other parts of the world are closing the gap. (See figure 7-1 and appendix tables 7-1, 7-2, and 7-3.)

## Chapter Organization

This chapter begins with a review of the market competitiveness of industries that rely heavily on R&D; these are often referred to as high-technology industries.[1] The importance of high-technology industries is linked to their high R&D spending and performance, which produce innovations that spill over into other economic sectors. Additionally, these industries help train new scientists, engineers, and other technical personnel. (See Nadiri 1993 and Tyson 1992.) The market competitiveness of a nation's technological advances, as embodied in new products and processes associated with these industries, can also serve as an indicator of the effectiveness of that country's S&T enterprise. The marketplace provides a relevant economic evaluation of a country's use of S&T.

U.S. high-technology industry competitiveness is assessed through an examination of market share trends worldwide, at home, and in various regions of the world. New data on royalties and fees generated from U.S. imports and exports of technological know-how are used to gauge U.S. competitiveness when technological know-how is sold or rented as intangible (intellectual) property.

The chapter explores several leading indicators of technology development (1) via an examination of changing emphases in industrial R&D among the major industrial countries and (2) through an extensive analysis of patenting trends. New information on international patenting trends of U.S. foreign inventors in several important technologies is presented.

The chapter concludes with a presentation of information on trends in venture capital disbursements. Venture capital is an important source of funds used in the formation and expansion of small high-technology companies. This section examines venture capital disbursements by stage of financing and by technology area in the United States.

# U.S. Technology in the Marketplace

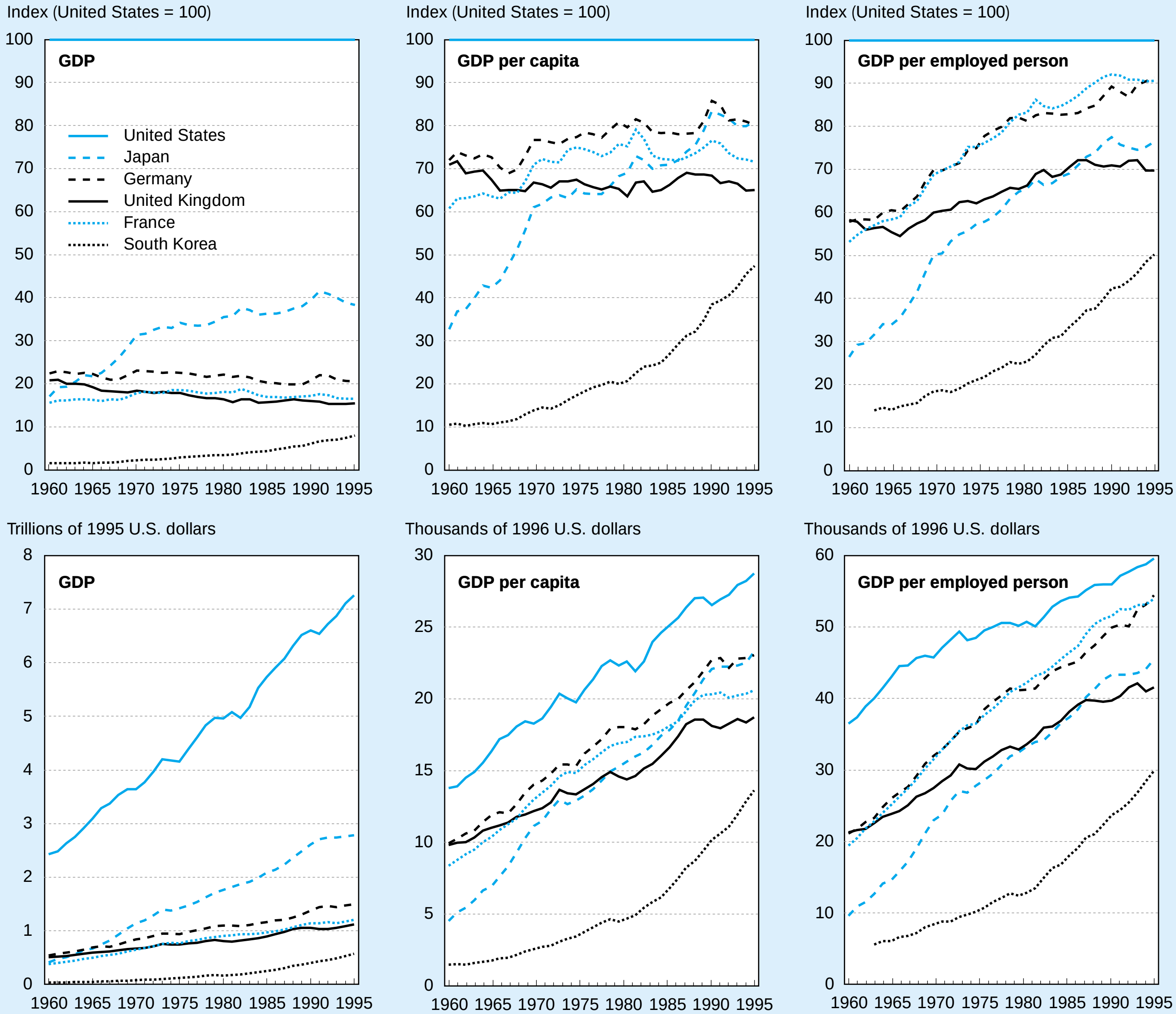
Most countries in the world acknowledge a symbiotic relationship between national investments in S&T and competitiveness in the marketplace: S&T support business competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, the health of the nation's economy becomes a performance measure for the national investment in R&D and in S&E.

This section discusses U.S. "competitiveness," broadly defined here as the ability of U.S. firms to sell products in the international marketplace. A great deal of attention is given to science-based industries producing products that embody above-average levels of R&D in their development (hereafter referred to as *high-technology industries*). OECD currently identifies four industries as high-technology based on their high R&D intensities: aerospace, computers and office machinery, electronics-communications, and pharmaceuticals.[2]

[1]In this chapter, high-technology industries are identified using R&D intensities calculated by the OECD. There is no single preferred methodology for identifying high-technology industries. The identification of those industries considered to be high-technology has generally relied on a calculation comparing R&D intensities. R&D intensity, in turn, has typically been determined by comparing industry R&D expenditures and/or numbers of technical people employed (such as scientists, engineers, and technicians) to industry value added or the total value of its shipments.

[2]In designating these high-technology industries, the OECD took into account both direct and indirect R&D intensities for 10 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, the Netherlands, Denmark and Australia. Direct intensities were calculated by the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was given a weight according to its share in the total output of the 10 countries using purchasing power parities as exchange rates. Indirect intensity calculations were made using technical coefficients of industries

Figure 7-1.
**International economic comparisons**




NOTE: Country GDPs were determined with 1993 purchasing power parities using the Elteto-Köves-Szulc (EKS) aggregation method and 1996 U.S. dollars (1995 U.S. dollars for aggregate GDP).

See appendix tables 7-1, 7-2, and 7-3. *Science & Engineering Indicators – 2000*

There are several reasons why high-technology industries are important to nations:

- ♦ High-technology firms are associated with innovation. Firms that innovate tend to gain market share, create new product markets, and/or use resources more productively (NRC, Hamburg Institute for Economic Research, and Kiel Institute for World Economics 1996; Tassey 1995).
- ♦ High-technology firms are associated with high value added production and success in foreign markets which helps to support higher compensation to the workers they employ (Tyson 1992).
- ♦ Industrial R&D performed by high-technology industries has other spillover effects. These effects benefit other com-

on the basis of input-output matrices. The OECD then assumed that for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (1993).

mercial sectors by generating new products and processes that can often lead to productivity gains, business expansions, and the creation of high-wage jobs (Nadiri 1993, Tyson 1992, and Mansfield 1991).

## The Importance of High-Technology Industries

The global market for high-technology goods is growing at a faster rate than that for other manufactured goods, and economic activity in high-technology industries is driving national economic growth around the world.[3] During the 18-year period examined (1980–97), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.2 percent compared with a rate of 2.7 percent for other manufactured goods.[4] Global economic activity was especially strong at the end of the period (1994–97), when high-technology industry output grew at more than 11 percent per year—more than four times the rate of growth for all other manufacturing industries. (See appendix table 7-4.) Output by the four high-technology industries—those identified as being the most research intensive—represented 7.1 percent of global production of all manufactured goods in 1980; by 1997, this output represented 11.9 percent.

During the 1980s, the United States and other high-wage countries increasingly moved resources toward the manufacture of higher-value, technology-intensive goods often referred to as high-technology manufactures. In 1989, U.S. high-technology manufactures represented nearly 11 percent of total U.S. production of manufactured output, up from 9.6 percent in 1980. High-technology manufactures also accounted for growing shares of total production for European nations, although to a lesser degree than that seen in the United States. The one exception was the United Kingdom where the transition to high technology during the 1980s was similar to that in the United States. High-technology manufactures represented just 9 percent of the United Kingdom's total manufacturing output in 1980 and nearly 11 percent by 1989. The Japanese economy led all other major industrial countries in its concentration on high-technology industries during the 1980s. In 1980, high-technology manufactures accounted for about 8 percent of total Japanese production, approached 11 percent in 1984, and then increased to 11.6 percent in 1989. (See the sidebar, "International Activity in High-Technology Service Industries.")

Data for the 1990s show an increased emphasis on high-technology manufactures among the major industrial countries. (See figure 7-4.) In 1997, high-technology manufactures were estimated to represent 15.7 percent of manufacturing output in Japan, 14.7 percent in the United States, 11.7 percent in the United Kingdom, and 8.3 percent each in France and Germany. Two other Asian countries, China and South Korea, typify how important R&D-intensive industries have become to the newly industrialized economies. In 1980, high-technology manufactures accounted for less than 7 percent of China's total manufacturing output; this proportion jumped

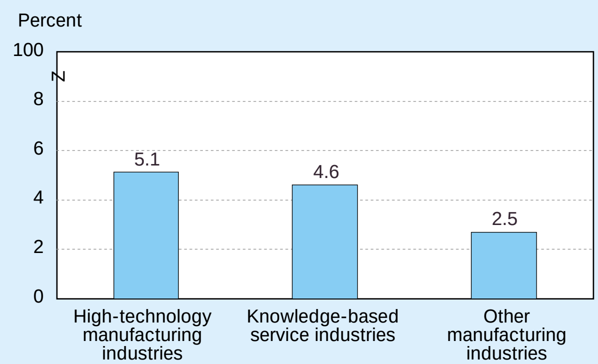
[3]This section is based on data reported by the WEFA Group in its Global Industry Model database. This database provides production data for 68 countries and accounts for more than 97 percent of global economic activity.

[4]Knowledge-based service sector industries grew at an average annual inflation-adjusted rate of 4.6 percent during this period.

## International Activity in High-Technology Service Industries

For several decades, revenues generated by U.S. service sector industries have grown faster than revenues generated by the Nation's manufacturing industries. Data collected by the U.S. Department of Commerce show that the U.S. service sector's share of the U.S. GDP grew from 49 percent in 1959 to 64 percent in 1997 (See appendix table 9-4.) Service sector growth has in large part been fueled by industries often described as "knowledge-based" industries—those incorporating science, engineering, and technology in the services being provided or in the delivery of those services. Prominent examples of these "knowledge-based" industries include communication services, financial services, business services (including computer software–related services), educational services, and health services. These industries have been growing nearly as fast as the high-technology manufacturing sector discussed earlier. (See figure 7-2.)

Figure 7-2.
**Average annual rates of growth in three U.S. economic sectors: 1980–97**




See appendix tables 7-4 and 7-5.

*Science & Engineering Indicators – 2000*

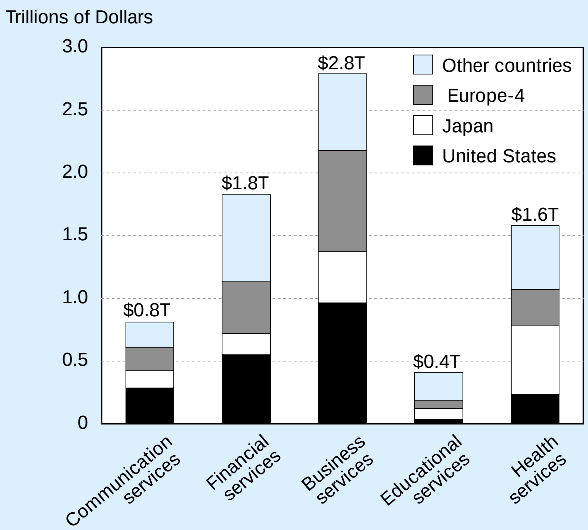
New data provided by the WEFA Group tracks overall revenues earned by these industries in 64 countries.* Similar to the value of production or data on total shipments previously discussed for high-technology manu-

*Unlike that for manufacturing industries, national data tracking activity in many of the hot new service sectors are limited in the level of industry disaggregation that is available and the types of activity for which national data are collected.

facturing industries, these data permit an examination of the global U.S. position in each of the service sector industries. (See figure 7-3 and appendix table 7-5.)

Combined worldwide sales in these five service sector industries exceeded $7.4 trillion in 1997, up from $5.8 trillion in 1990 and $3.4 trillion in 1980 (1997 dollars). The United States was the leading national provider of high-technology services, responsible for more than 28–30 percent of total world service revenues during the 1980s and for about 27 percent of revenues during the 1990–97 period.

Figure 7-3.
**Global activity in five knowledge-based service industries in 1997**




NOTE: Europe-4 refers to the four largest European economies: France, Germany, Italy, and the United Kingdom.

See appendix table 7-5. *Science & Engineering Indicators – 2000*

Business services, which include computer and data processing services, research and engineering services, and other business services, is the largest of the five-industry service sector and accounted for nearly 38 percent of revenues in 1997. The U.S. business service industry is the largest in the world with 34.4 percent of industry revenues in 1997. Japan was second at 14.7 percent, followed by Germany with 10.0 percent and France at 9.8 percent. Unfortunately, data on individual business services by country are not available.

Services provided by financial institutions represent the second largest of the five service industries examined, and accounted for nearly 25 percent of revenues in 1997. Among the three largest advanced nations, the U.S. financial services industry is the largest with 30.0 percent of world industry revenues in 1997. Japan was again second at 9.3 percent followed by Germany at 6.6 percent.

Communications services, which include telecommunications and broadcast services, represent the third largest of the five service industries examined and accounted for 10.9 percent of revenues in 1997. In what many consider the most technology-driving of the service industries, the U.S. industry has the most dominant position. In 1997, U.S. communications firms generated revenues that accounted for 35.2 percent of world revenues, more than twice the share held by Japanese firms, and nearly five times that held by German firms.

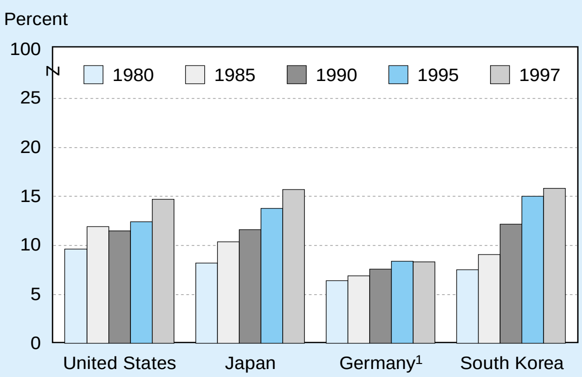
More than the first three, the remaining two knowledge-based service industries—health services and educational services—operate on the edge of government services. Health services industry data examined here track services provided by private hospitals, doctors, and miscellaneous medical services. Educational services include commercial education and library services. In both health and education services, Japan's industries are the largest in the world and lead the next largest national industry—that in the United States—by large margins. Japan's share of world revenues in the health services industry was 34.6 percent in 1997—more than twice the share for the U.S. health services industry. Of the four largest European economies, Italy had the largest health service industry. In educational services, Japan's leading share of the world revenues was lower than that in health services—21.7 percent versus 34.6 percent—but this leading share was two and a half times greater than the second largest national industry in the United States. Italy once again had the next largest share, 4.8 percent, although the other large European economies had educational services nearly as big. Educational services represented the smallest of the five knowledge-based service industries with about one-seventh of the revenues generated by the business services industry worldwide.

to 11.6 percent in 1989 and reached 14.8 percent in 1997—about the same as in the United States. In 1997, high-technology manufacturing in South Korea accounted for about the same percentage of total output as in Japan (15.8 percent) and almost twice the percentage of total manufacturing output in France and Germany.

## Share of World Markets

Throughout the 1980s, the United States was the leading producer of high-technology products, and was responsible for more than one-third of total world production from 1980 to 1987, and for about 30 percent of world production for the rest of the decade. U.S. world market share held fairly steady

Figure 7-4.
**High-technology industries' share of total manufacturing output**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

[1]German data are for West Germany only.

during much of the 1990s and moved up slightly in both 1996 and 1997. (See figure 7-5.) In 1997, production by U.S. high-technology industry accounted for nearly 32 percent of world high-technology production.

While U.S. high-technology industry struggled to maintain market share during the 1980s, the Asian global market share in high-technology industries followed a path of steady gains. In 1989, Japan accounted for 24 percent of the world's production of high-technology products, moving up 4 percentage points since 1980. Japan continued to gain market share through 1991. Since then, however, Japan's market share has dropped steadily, falling to under 22 percent of world production in 1997 after accounting for nearly 26 percent in 1991.

By comparison, many European nations' share of world high-technology production is much lower. Germany produced about 8 percent of world high-technology production in 1980, about 7 percent in 1989, and less than 6 percent in 1997. Shares for the United Kingdom declined in a similar fashion. In 1980, United Kingdom's high-technology industry produced about 7 percent of world output, it dropped to about 6 percent in 1989, and to 4.4 percent by 1997. French high-technology industry never accounted for more than 4.5 percent of world high-technology output during the period examined, and its shares trended downward to about 3 percent by 1997. Italy's shares were the lowest among the four large European economies, ranging from a high of about 2.5 percent of world high-technology production in 1980 to a low of about 1 percent in 1997.

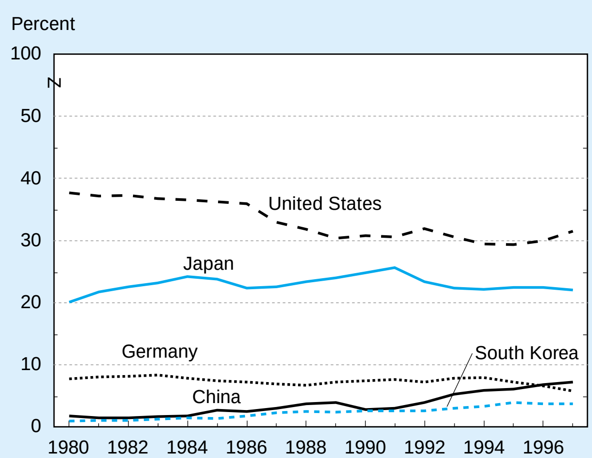
Developing Asian nations made the most dramatic gains since 1980. China's market share doubled during the 1980s, moving from 1.8 percent in 1980 to 3.9 in 1989, and is on track to double again during the 1990s with its latest share reaching 7.2 in 1997. Production by China's high-technology industries in 1997 was larger than any European nation. Like China, high-technology industries in South Korea quickly gained market during the 1980s and expanded that market share in the 1990s. Starting with less than 1 percent in 1980, output by high-technology industries in South Korea accounted for 2.4 percent of world output in 1989 and 3.7 percent by 1997. Compared with high-technology production in the four largest European countries, South Korea's share of world production in 1997 was smaller than that in either Germany or United Kingdom, but larger than that produced by high-technology industries in both France and Italy.

## Global Competitiveness of Individual Industries

In each of the four industries that make up the high-technology group, the United States maintained strong, if not leading, market positions during the 18-year period examined. Yet competitive pressures from a growing cadre of high-technology–producing nations contributed to a decline in global market share for two U.S. high-technology industries during the 1980s: aerospace and communications equipment. Since then, both of these industries—in particular, communications equipment—reversed their downward trends and gained market share in the mid- to late 1990s. (See figure 7-6.)

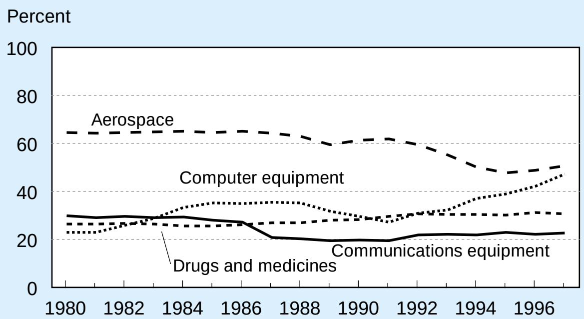
The U.S. aerospace industry, the Nation's strongest high-technology industry in terms of world market share, was the one high-technology industry to lose market share in the 1980s and again in the 1990s. For much of the 1980s, the U.S. aerospace industry supplied about two-thirds of world demand. By the late 1980s, the U.S. share of the world aerospace market began an erratic decline and dropped to under 60 percent by 1989. The U.S. aerospace industry maintained this market share up until 1993 when market share, once again, began to slip, falling to its lowest level for the period (under 48 percent) in 1995. The U.S. share recovered somewhat during the following two years reaching 51 percent of the world market in 1997. While European aerospace industries made some gains during this time, China's industry recorded large gains in global market share beginning in 1992. In 1980, China

Figure 7-5.
**Country share of global high-technology output**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

Figure 7-6.
**U.S. global output share, by high-technology industry**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

supplied about 2.9 percent of world aircraft shipments; by 1997, its share had increased to nearly 16 percent. (See figure 7-7.)[5]

As previously noted, two U.S. high-technology industries lost market share during the late 1980s and then reversed that trend during the 1990s. By 1997, the United States was the number one supplier of computer equipment in the world and the second leading supplier of communications equipment behind Japan.

Of the four high-technology industries, only the U.S. aerospace and U.S. pharmaceutical industries managed to retain their number one rankings throughout the 18-year period. Of these two, only the U.S. pharmaceutical industry had a larger share of the global market in 1997 than in 1980.

The United States is considered a large, open market. These characteristics benefit U.S. high-technology producers in two important ways. First, supplying a market with many domestic consumers provides scale effects to U.S. producers in the form of potentially large rewards for the production of new ideas and innovations (Romer 1996). Second, the openness of the U.S. market to foreign-made technologies pressures U.S. producers to be inventive and to move toward more rapid innovation to maintain domestic market share.

This discussion of world market shares shows that U.S. producers are leading suppliers of high-technology products to the global market. That evaluation incorporates U.S. sales to domestic, as well as to foreign customers. In the next sections, these two markets are examined separately.

## Exports by High-Technology Industries

While U.S. producers reaped many benefits from having the world's largest home market (as measured by GDP), mounting trade deficits highlight the need to also serve demand in foreign markets. U.S. high-technology industries have traditionally been more successful exporters than other U.S. industries. Consequently, high-technology industries have attracted considerable attention from policymakers as they seek ways to return the United States to a more balanced trade position.

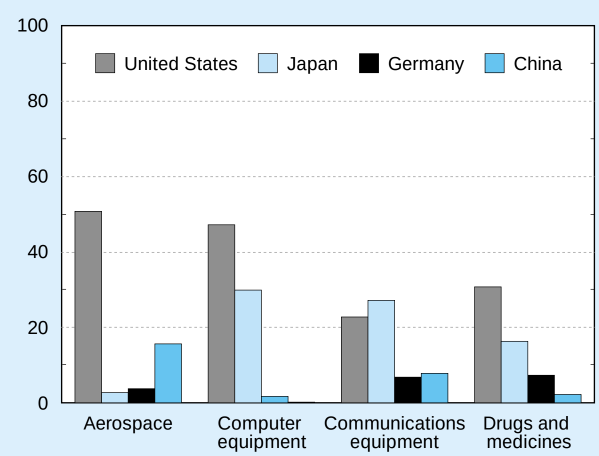
### *Foreign Markets*

Despite its domestic focus, the United States has been an important supplier of manufactured products in foreign markets throughout the 1980–97 period. From 1994 to 1997, the United States was the leading nation exporter of manufactured goods and accounted for about 12 percent of world exports.

U.S. high-technology industries have contributed to this strong export performance of the nation's manufacturing industries. (See figure 7-8.) During the same 18-year period, U.S. high-technology industries accounted for between 17 and 25 percent of world high-technology exports—which is at times twice the level achieved by all U.S. manufacturing industries. In 1997, the latest year for which data are available, exports by U.S. high-technology industries accounted for 18.1 percent of world high-technology exports. Japan was second, accounting for 9.1 percent, followed by the United Kingdom with 8.3 percent.

The drop in U.S. share over the 18-year period is in part the result of the emergence of high-technology industries in newly industrialized economies, especially within Asia. Singapore and South Korea are two examples. In 1980, high-technology industries in Singapore and South Korea accounted for about 2.6 percent and 1.5 percent of world high-technology exports, respectively. Both nations' market shares doubled by the late 1980s. The latest data for 1997 show Singapore's share reaching 8.0 percent and South Korea's share reaching 5.4 percent.

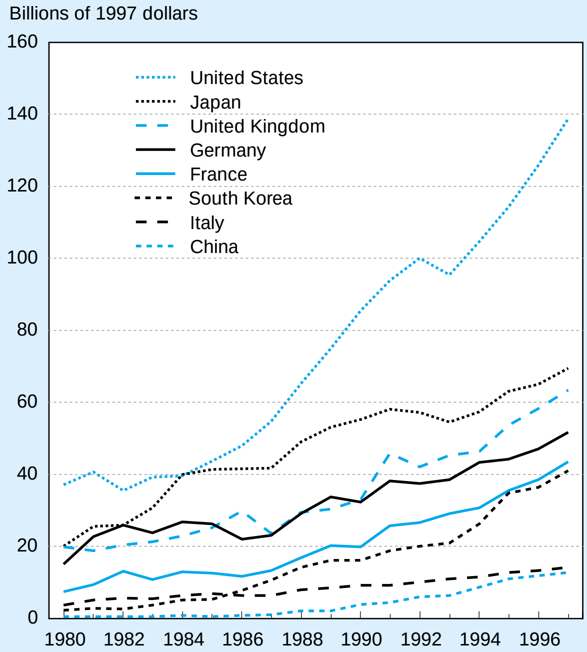
Figure 7-7.
**Global output share, by selected country and high-technology industry: 1997**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

[5]Industry experts in the United States contacted to confirm such a large China presence in the market for aerospace products suggest that China's production may be more heavily concentrated in satellite launch equipment and noncommercial production than in commercial aircraft.

Figure 7-8.
**High-technology exports**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

### *Industry Comparisons*

Throughout the 18-year period, individual U.S. high-technology industries either led in exports or were second to the leader in each of the four industries included in the high-technology grouping. The most current data (1997) show the United States as the export leader in three industries and third in just one—drugs and medicines. (See figure 7-9.)

U.S. industries producing aerospace, computers, and drugs and medicines all accounted for smaller export shares in 1997 than in 1980. The communications equipment industry was the sole U.S. high-technology industry to improve its share of world exports during the period. By comparison, the share of world exports held by Japan's communications equipment industry dropped steadily after 1985—eventually falling to 12.3 percent by 1997 from a high of 33.6 percent just 12 years earlier. Once again the newly industrialized economies of Asia demonstrated an ability to produce high-technology goods to world-class standards and were rewarded with great success in selling to foreign markets. In 1997, South Korea supplied 7.8 percent of world communications product exports, up from just 2.9 percent in 1980. Singapore supplied 9.9 percent of world computer equipment exports in 1997, up from 4.8 percent in 1980. Other Asian newly industrialized economies have demonstrated strong capabilities in those two high-technology industries.

## Competition in the Home Market

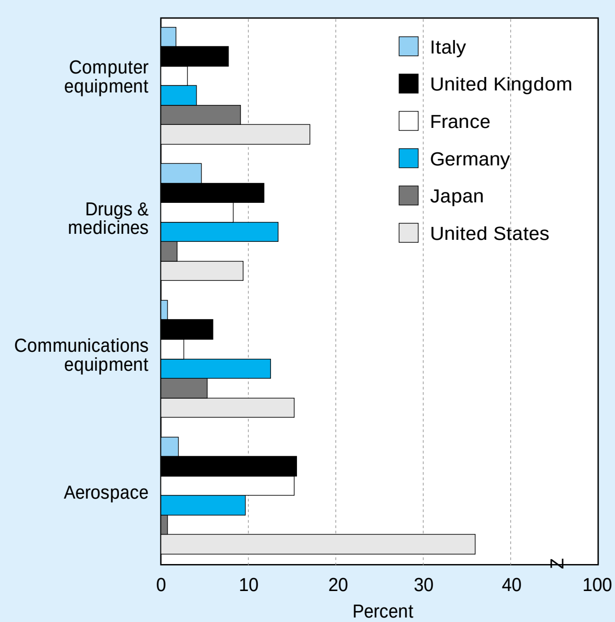
A country's home market is often thought of as the natural destination for the goods and services produced by domestic firms. For obvious reasons—including proximity to the customer and common language, customs, and currency—marketing at home is easier than marketing abroad.

With trade barriers falling and the number of foreign firms able to produce goods to world standards rising, however, product origin may be only one factor among many influencing the consumer's choice between competing products. Price, quality, and product performance often become equally or more important determinants guiding product selection. Thus, in the absence of trade barriers, the intensity of competition faced by domestic producers in their home market can approach—and, in some markets, may even exceed—the level of competition faced in foreign markets. Explanations for U.S. competitiveness in foreign markets may be found in the two dynamics of the U.S. market: the existence of tremendous domestic demand for the latest advanced technology products and the degree of world-class competition that continually pressures U.S. industry toward innovation and discovery.

### *National Demand for High-Technology Products*

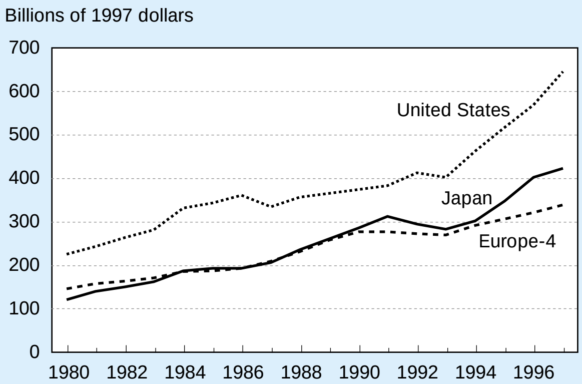
Demand for high-technology products in the United States far exceeds that in any other single country and is larger than the combined markets of the four largest European nations: Germany, the United Kingdom, France, and Italy. (See figure 7-10.) This was consistently the case for the entire 1980–97 period. Japan was the second largest market for high-tech-

Figure 7-9.
**Export market share in high-technology industries: 1997**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

Figure 7-10.
**National consumption of high-technology products**




NOTE: Europe-4 refers to the four largest European economies: Germany, France, the United Kingdom, and Italy.

See appendix table 7-4. *Science & Engineering Indicators – 2000*

nology products in the world, although its share of world consumption has generally declined since 1991. China again stands out. In 1980, China consumed less than 2 percent of world high-technology output—its demand doubled by the end of the decade and doubled again by 1997. The latest annual data (1997) show China's economy as the world's second largest consumer of aerospace products, trailing only the United States, and the fourth largest consuming nation of communications equipment, trailing the United States, Japan, and Germany.

### *National Producers Supplying the Home Market*

Throughout the 1980–97 period, the world's largest market for high-technology products, the United States, was served primarily by domestic producers—yet demand was increasingly met by a growing number of foreign suppliers. (See figure 7-11.) In 1997, U.S. producers supplied about 81.5 percent of the home market for high-technology products (aerospace, computers, communications equipment, and pharmaceuticals). In 1980, however, U.S. producers' share was much higher, about 92.5 percent.

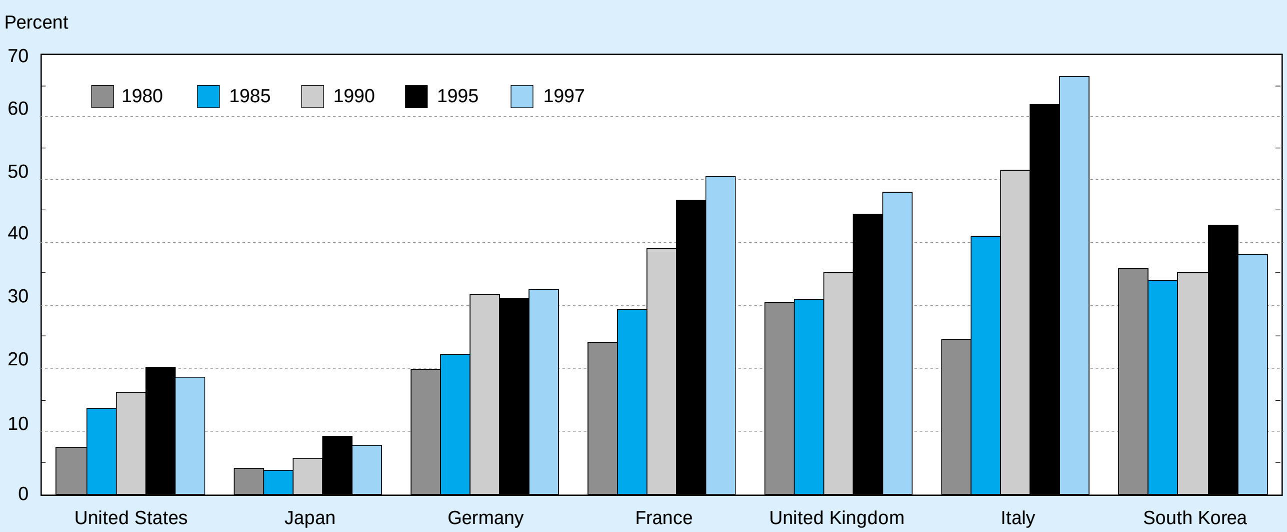
Other countries have experienced similar increased foreign competition in their domestic markets. This is especially true in Europe. A more economically unified European market has had the effect of making Europe an even more attractive market to the rest of the world. Rapidly rising import penetration ratios in the four large European nations during the latter part of the 1980s and throughout much of the 1990s reflect these changing circumstances. These data also highlight greater trade activity in European high-technology markets when compared with product markets for less technology-intensive manufactures.

The Japanese home market, the second largest national market for high-technology products and historically the most self-reliant of the major industrial countries, also increased its purchases of foreign technologies during the 18-year period, albeit slowly. In 1980, imports of high-technology manufactures supplied about 4 percent of Japanese domestic consumption, rising to 5.3 percent in 1989, and then to 7.8 percent by 1997.

## U.S. Trade Balance

The U.S. Bureau of the Census has developed a classification system for exports and imports of products that embody new or leading-edge technologies. This classification system allows trade to be examined in 10 major technology areas

Figure 7-11.
**Import share of domestic high-technology markets**




See appendix table 7-4. *Science & Engineering Indicators – 2000*

that have led to many leading-edge products. These 10 advanced technology areas are as follows:

- *Biotechnology*—The medical and industrial application of advanced genetic research toward the creation of new drugs, hormones, and other therapeutic items for both agricultural and human uses.
- *Life science technologies*—The application of scientific advances (other than biological) to medical science. For example, medical technology advances, such as nuclear resonance imaging, echocardiography, and novel chemistry, coupled with new production techniques for the manufacture of drugs, have led to new products that allow for the control or eradication of disease.
- *Opto-electronics*—The development of electronic products and components that involve emission or detection of light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- *Computers and telecommunications*—The development of products that process increasing volumes of information in shorter periods, including fax machines, telephone switching apparatus, radar apparatus, communications satellites, central processing units, computers, and peripheral units, such as disk drives, control units, modems, and computer software.
- *Electronics*—The development of electronic components (except opto-electronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that result in improved performance and capacity and, in many cases, reduced size.
- *Computer-integrated manufacturing*—The development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles that allow for greater flexibility in the manufacturing process and reduce the amount of human intervention.
- *Material design*—The development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- *Aerospace*—The development of technologies, such as most new military and civil airplanes, helicopters, spacecraft (with the exception of communications satellites), turbojet aircraft engines, flight simulators, and automatic pilots.
- *Weapons*—The development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.
- *Nuclear technology*—The development of nuclear production apparatus, including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges. Nuclear medical apparatus is included in life science rather than this category.

To be included in a category, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value. Since the characteristics of products the United States exports are likely to be different from the products the nation imports, experts evaluated exports and imports separately.

There is no single preferred methodology for identifying high-technology industries. Generally, this identification has relied on some calculation comparing R&D intensities. R&D intensity, in turn, has typically been determined by comparing industry R&D expenditures and/or numbers of technical people employed (such as scientists, engineers, and technicians) with industry value added or the total value of its shipments. These classification systems suffer from a degree of subjectivity introduced by the assignment of establishments and products to specific industries. The information produced by these R&D-intensity–based classification systems is often distorted by the inclusion of all products produced by the selected high-technology industries, regardless of the level of technology embodied in the product. In contrast, the advanced technology product system of trade data discussed here allows for a highly disaggregated, more focused examination of technology embodied in traded goods. To minimize the impact of subjective classification, the judgments offered by government experts are subsequently reviewed by other experts.

### The Importance of Advanced Technology Product Trade to Overall U.S. Trade

U.S. trade in advanced technology products accounted for an increasingly larger share of all U.S. trade (exports plus imports) in merchandise between 1990 and 1998. (See text table 7-1.) Total U.S. trade in merchandise exceeded $1.6 trillion in 1998; $343 billion involved trade in advanced technology products. Trade in advanced technology products accounts for a much larger share of U.S. exports than of imports (28 percent versus 17 percent in 1998) and makes a positive contribution to the overall balance of trade. After several years in which the surplus generated by trade in advanced technology products declined, that changed in 1996. In 1996 and again in 1997, exports of U.S. advanced technology products outpaced imports producing larger surpluses both years. In 1998, the slowdown in Asian economies led to a decline in exports to this region and a reduction in the surplus generated from U.S. trade in advanced technology products. (See figure 7-12 and text table 7-1.)

### Technologies Generating a Trade Surplus

During the 1990s, U.S. exports of advanced technology products generally exceeded imports in 8 of 10 technology

Text table 7-1.
**U.S. International trade in merchandise**
(Billions of U.S. Dollars)

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1994 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| Total exports (billions of U.S. dollars) ................ | 393.0 | 421.9 | 447.5 | 464.8 | 512.4 | 575.9 | 611.5 | 679.3 | 670.6 |
| Technology products (percent) ...................... | 24.1 | 24.1 | 23.9 | 23.3 | 23.6 | 24.0 | 25.3 | 26.4 | 27.8 |
| Other merchandise (percent) ......................... | 75.9 | 75.9 | 76.1 | 76.7 | 76.4 | 76.0 | 74.7 | 73.6 | 72.2 |
| Total imports (billions of U.S. dollars)…. ........... | 495.3 | 488.1 | 532.4 | 580.5 | 663.8 | 749.4 | 799.3 | 877.3 | 918.8 |
| Technology products (percent) ...................... | 12.0 | 13.0 | 13.5 | 14.0 | 14.8 | 16.7 | 16.3 | 16.8 | 17.1 |
| Other merchandise (percent) ......................... | 88.0 | 87.0 | 86.5 | 86.0 | 85.2 | 83.3 | 83.7 | 83.2 | 82.9 |
| Total trade (billions of U.S. dollars) ................... | 888.3 | 910.0 | 979.9 | 1,045.3 | 1,176.2 | 1,325.3 | 1,410.8 | 1,556.6 | 1,589.4 |
| Technology products (percent) ...................... | 17.3 | 18.1 | 18.3 | 18.1 | 18.6 | 19.9 | 20.2 | 21.0 | 21.6 |
| Other merchandise (percent) ......................... | 82.7 | 81.9 | 81.7 | 81.9 | 81.4 | 80.1 | 79.8 | 79.0 | 78.4 |

NOTE: Total trade is the sum of total exports and total imports.

SOURCE: U.S. Bureau of the Census, Foreign Trade Division <<http://www.fedstats.gov>>1999.

*Science & Engineering Indicators – 2000*

areas.[6] Trade in aerospace technologies consistently produced the largest surpluses for the United States during the 1990s. Those surpluses narrowed in the mid-1990s as competition from Europe's Airbus Industrie challenged U.S. companies' preeminence both at home and in foreign markets. Aerospace technologies generated a net inflow of $25 billion in 1990, and almost $29 billion in 1991 and 1992. Trade balances then declined 13 percent in 1993, 9 percent in 1994, and 14 percent in 1995. Since then, annual trade balances in aerospace technologies have grown each year. In 1998, the U.S. trade in aerospace technologies produced a net inflow of $39 billion, the largest surplus recorded during the 1990–98 period.

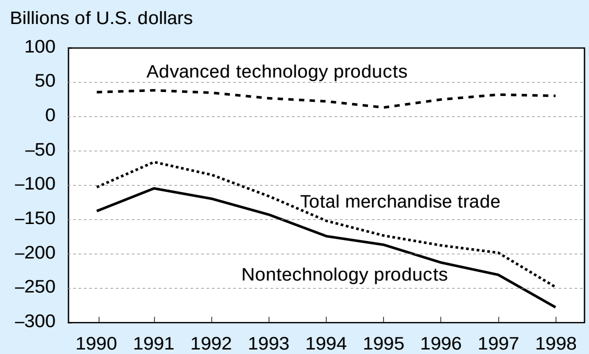
In five other the technology areas, trade is fairly balanced, with only a slight edge to U.S. exports over imports. U.S. trade in biotechnologies, computer integrated manufacturing technologies, material design, weapons, and nuclear technologies each showed surpluses of less than $2 billion in 1998.

Electronics, a technology area where U.S. imports typically exceeded exports, showed a trade surplus in both 1997 and 1998. The annual trade deficit in this technology area grew annually from 1990 to 1994 and then began to narrow. In 1998, U.S. exports of electronics exceeded imports by $4.2 billion. Economic problems in Asia and a stronger U.S. dollar may have lowered the level of electronics products imported from Asia.

### *Technologies Generating a Trade Deficit*

In 1998, trade deficits were recorded in three technology areas—computers and telecommunications, opto-electronics, and life science technologies. The trends for each of these technology areas are quite different. Only opto-electronics

Figure 7-12.
**U.S. merchandise trade balance**




Calculated from text table 7-1.

*Science & Engineering Indicators – 2000*

showed trade deficits in each of the nine years examined. U.S. trade in life science technologies had consistently generated annual trade surpluses up until 1998. In 1998, life science exports to Asia fell by 18 percent, and imports from Europe rose sharply, especially from Germany and Ireland. Interestingly, in a technology area where the United States is considered at the forefront—computers and telecommunications—annual U.S. imports have exceeded exports consistently since 1992. Nearly three-quarters of all U.S. imports in this technology area are produced in Asia.[7]

### *Top Nation Customers, by Technology Area*

Japan and Canada are U.S. industry's largest nation customers for U.S. technology products. Each country is the destination for about 11 percent of total U.S. technology exports.

[6]U.S. trade in software products is not a separate ATP category but is included in the ATP category covering computers and telecommunications products. In order to better examine this important technology area, U.S. trade in software products was broken out from the computers and telecommunications category creating an eleventh category.

[7]The Bureau of the Census is not able to identify the degree to which this trade is between affiliated companies.

European countries are also important consumers of U.S. technology products. New markets have developed in several newly industrialized and developing economies, especially in Asia. Technology purchases by these economies now approach levels sold to many of the advanced European countries.

Japan and Canada are among the top three customers across a broad range of U.S. technology products. Japan ranks among the top 3 in 10 of 11 technology areas—Canada in 8. (See figure 7-13.) The United Kingdom is a leading consumer of U.S. products in five areas: opto-electronics, computers and telecommunications, aerospace, weapons and computer software. Although several other advanced nations are also important customers for particular U.S. technologies, notably Germany (life science technologies and nuclear technologies) and Belgium (biotechnology), several of the newly industrialized and emerging Asian economies now rank among the largest consumers for U.S. technology products.

### *Top Nation Suppliers, by Technology Area*

The United States is not only an important exporter of technologies to the world, but it is also a consumer of foreign-made technologies. Imported technologies enhance productivity of U.S. firms and workers, improve health care for U.S. residents, and offer U.S. consumers more choices.

The leading economies in Asia and Europe are important suppliers to the U.S. market in each of the 11 technology areas. (See figure 7-14.) Japan is a major supplier in five advanced technology categories, Germany in four. France, Canada, and the United Kingdom also supply a wide variety of technology products to the United States and are among the top three in several advanced technology areas.

A large volume of technology products comes from newly developed and developing Asian economies, in particular Malaysia, South Korea, Taiwan, and China. Growing technology product imports from these Asian economies and from other regions into one of the most demanding markets in the world indicate a further widening of technological capabilities globally.

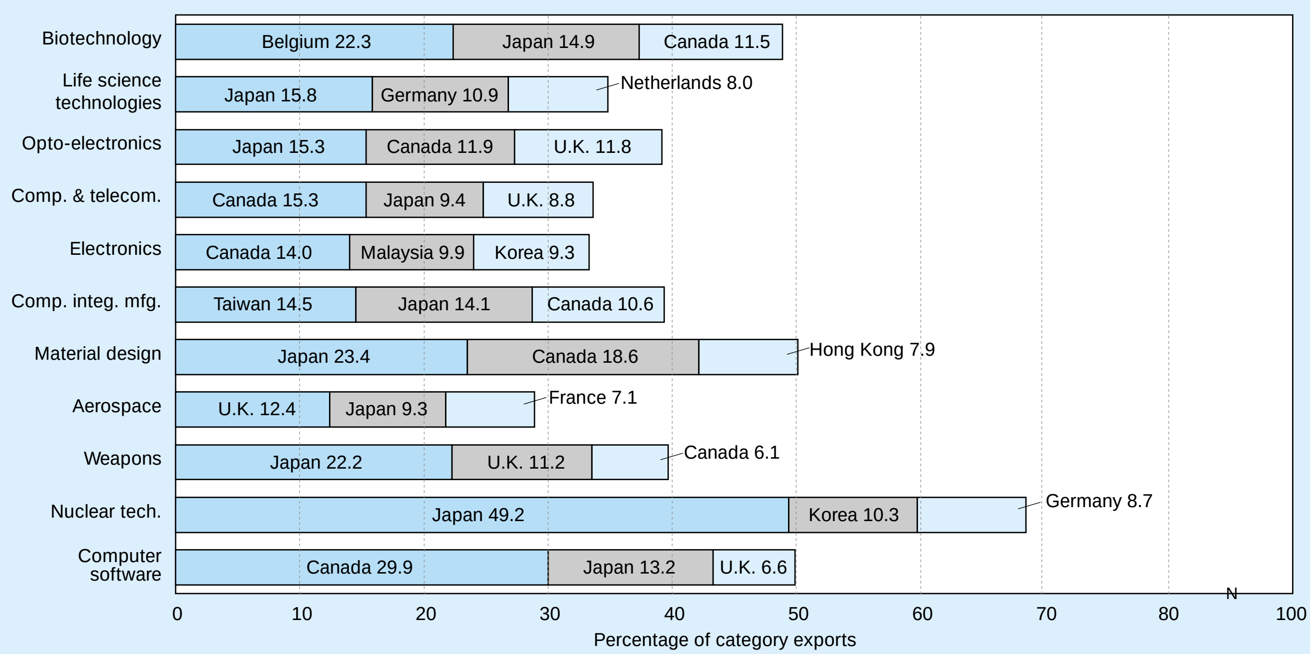
## U.S. Royalties and Fees Generated from Trade in Intellectual Property

The United States has traditionally maintained a large surplus in international trade of intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. These transactions generate revenues in the form of royalties and licensing fees.

### *U.S. Royalties and Fees from All Transactions*

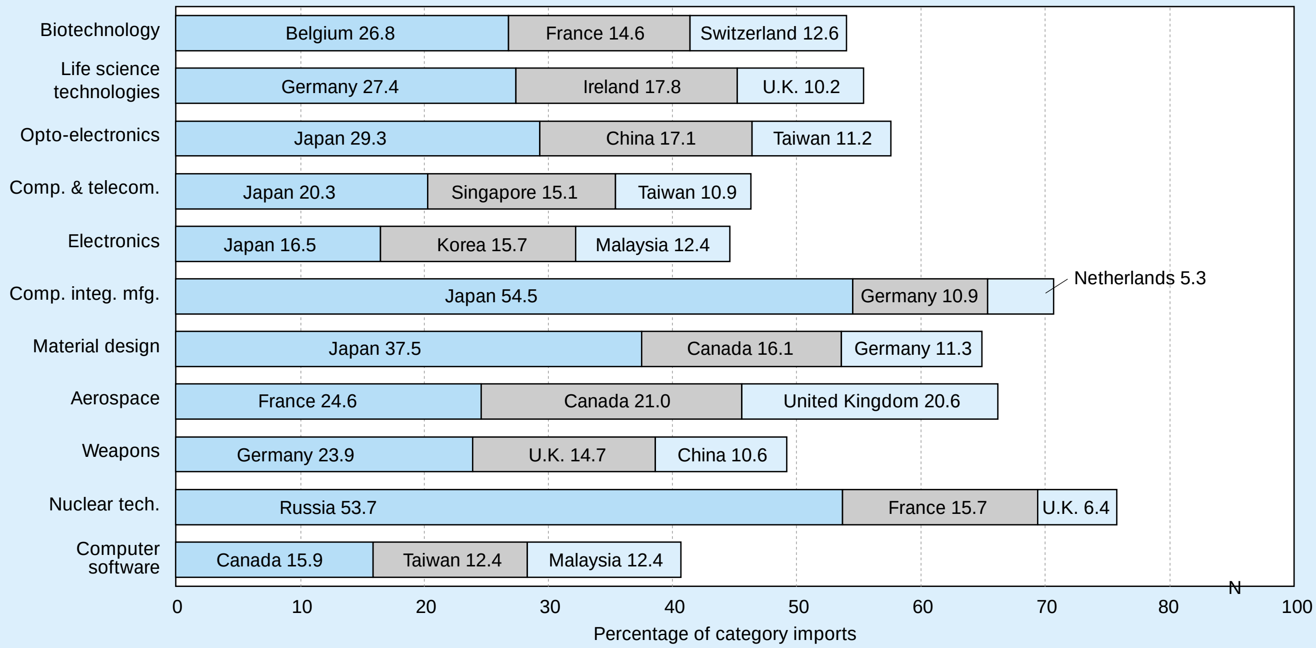
Total U.S. receipts from all trade in intellectual property reached $33.7 billion in 1997. This level extended a decade of steady increases that has resulted in a doubling of U.S. receipts since 1990. During the 1987–96 period, U.S. receipts were generally four to five times as large as U.S. payments to foreign firms for transactions involving intellectual property. The gap narrowed in 1997 as U.S. payments increased by 20

Figure 7-13.
**Three largest export markets for U.S. technology products: 1998**




See appendix table 7-6. *Science & Engineering Indicators – 2000*

Figure 7-14.
**Top three foreign suppliers of technology products to the United States: 1998**




See appendix table 7-6.

*Science & Engineering Indicators – 2000*

percent over the previous year and U.S. receipts rose less than 3 percent. Despite the much larger increase in payments, annual receipts from total U.S. trade in intellectual property in 1997 were still more than three and one-half times greater than payments. U.S. trade in intellectual property produced a surplus of $24.3 billion in 1997, down slightly from the nearly $25 billion surplus recorded a year earlier. Most (about 75 percent) of the transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates. (See figure 7-15.)[8]

Exchanges of intellectual property among affiliates have grown at about the same pace as those among unaffiliated firms. These trends suggest both a growing internationalization of U.S. business and a desire by U.S. firms to retain a high level of control on any intellectual property leased overseas.

### *U.S. Royalties and Fees from Trade in Technical Knowledge*

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in technical know-how. The following data describe transactions between unaffiliated firms where prices are set through a market-based negotiation. Therefore, they may reflect better the exchange of technical know-how and its market value at a given point in time than do data on exchanges among affiliated firms. When receipts (sales of technical know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. The record of resulting receipts and payments also provides an indicator of the production and diffusion of technical knowledge.

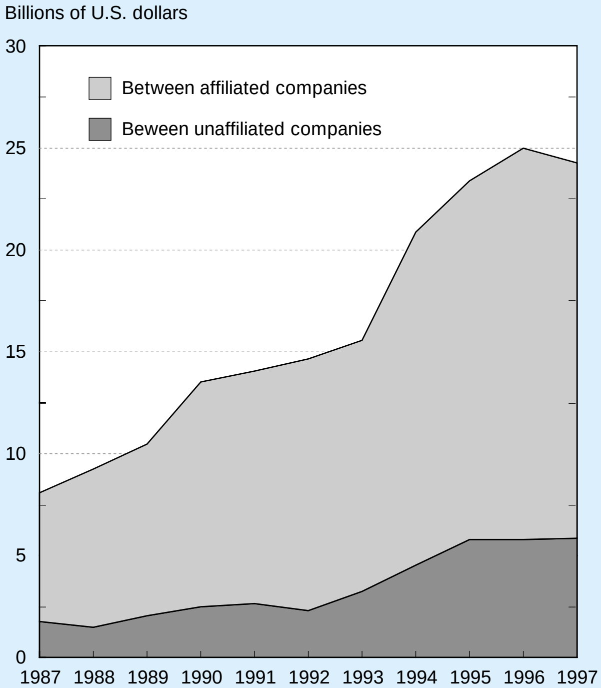
The United States is a net exporter of technology sold as intellectual property. During the past decade, royalties and fees received from foreign firms have been, on average, three times those paid out by U.S. firms to foreigners for access to their technology. U.S. receipts from such technology sales were about $3.3 billion in 1997, down slightly from $3.5 billion in 1996, but still nearly double that reported for 1987. (See figure 7-16 and appendix table 7-8.)

Japan is the largest consumer of U.S. technology sold as intellectual property. In 1997, Japan accounted for about 44 percent of all such receipts. The EU countries together represented about 22 percent. Another Asian country, South Korea, is the second largest consumer of U.S. technology sold as intellectual property, accounting for nearly 12 percent of U.S. receipts in 1997. South Korea has been a large consumer of U.S. technological know-how since 1988, when it accounted for 5.5 percent of U.S. receipts. South Korea's share rose to 10.7 percent in 1990, and reached its highest level, 17.3 percent, in 1995.

To a large extent, the U.S. surplus in the exchange of intellectual property is driven by trade with Asia. In 1997, U.S. receipts (exports) from technology licensing transactions were

[8]An affiliate refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity of another country to the extent of 10 percent or more of its voting stock for an incorporated business or an equivalent interest for an unincorporated business.

Figure 7-15.
**U.S. trade balance in intellectual property**




See appendix table 7-7. *Science & Engineering Indicators – 2000*

nearly six times U.S. firm payments (imports) to Asia. As previously noted, Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property. Together these countries accounted for more than 55 percent of total receipts in 1997.

The U.S. experience with Europe has been very different from that with Asia. Over the years, the balance of U.S. trade with Europe in intellectual property has bounced back and forth, showing either a small surplus or deficit until 1995. In 1995, United States–Europe trade produced a considerably larger surplus for the United States compared with earlier years, the result of a sharp decline in U.S. purchases of technical know-how from the smaller European countries that year. The following year also showed a large surplus, but this time it was driven by a jump in receipts from the larger European countries. The latest data (1997) show receipts from the larger European countries dropping back to pre-1996 levels, which caused a considerably smaller surplus from U.S. trade with Europe in intellectual property in 1997.

Foreign sources for U.S. firm purchases of technical know-how have changed somewhat over the years, with increasing amounts of coming from Japan. About one-fourth of 1997 U.S. payments for technology sold as intellectual property were made to Japanese firms. Europe still accounts for slightly more than 60 percent of the foreign technical know-how purchased by U.S. firms with France, Germany, and the United Kingdom being the principal European suppliers. Since 1992, however, Japan has been the single largest foreign supplier of technical know-how to U.S. firms.

## International Trends in Industrial R&D

In high-wage countries like the United States, industries stay competitive in a global marketplace through innovation (Council on Competitiveness 1999). Innovation can lead to better production processes and better-performing products (for example, those that are more durable or more energy efficient). It can thereby provide the competitive advantage high-wage countries require when competing with low-wage countries.

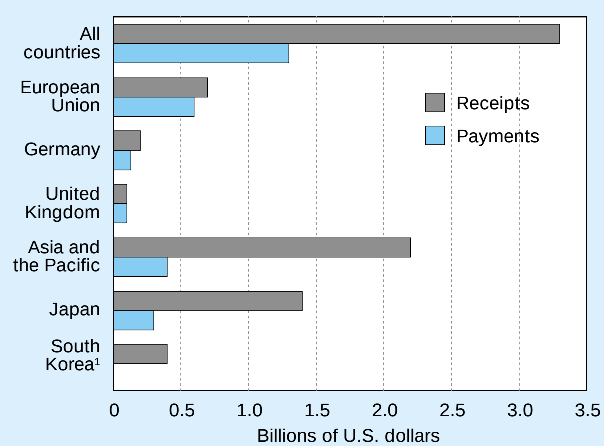
R&D activities serve as an incubator for the new ideas that can lead to new products, processes, and industries. Though they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are associated with many of the important new ideas that have helped shape modern technology.

U.S. industries that traditionally conduct large amounts of R&D have met with greater success in foreign markets than less R&D-intensive industries and have been more supportive of higher wages for their employees.[9] Moreover, trends in industrial R&D performance serve as leading indicators of future technological performance. This section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries of the United States, Japan, and the European Union.[10]

[9]See the section, "U.S. Technology in the Marketplace," earlier in this chapter for a presentation of recent trends in U.S. competitiveness in foreign and domestic product markets.

[10]This section uses data from the OECD's Analytical Business Enterprise R&D database (Paris, April 1999) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense- and nondefense-related) carried out in the industrial sector, regardless of funding source. For an examination of U.S. industrial R&D by funding source and type of research performed, see chapter 2 in this volume, "U.S. and International Research and Development: Funds and Alliances."

Figure 7-16.
**U.S. royalties and fees generated from the exchange of industrial processes between unaffiliated companies: 1997**




[1]Data withheld to avoid disclosing operations of individual companies.
See appendix table 7-8. *Science & Engineering Indicators – 2000*

## Overall Trends

The United States has long led the industrial world in the performance of industrial R&D. During the past two decades, as technology has become more closely associated with firm success in the global marketplace, other advanced economies have put more of their resources into R&D and have increased their industrial R&D performance at an annual growth rate that exceeds that in the United States. (See the sidebar, "Economists Estimate Rates of Return to Private R&D Investment.")

Consequently, the U.S. share of total industrial R&D performed by all OECD member countries fell between 1973 and 1990. (See figure 7-17.) Despite this decline, the United States remained the leading performer of industrial R&D by a wide margin, even surpassing the combined R&D of the 15-nation European Union. For its part, Japan—in keeping with its belief in the economic benefits of investments in R&D—rapidly increased R&D spending in the 1970s and 1980s that led to a large increase in its share of total OECD R&D by 1990. Data for 1996 show U.S. industrial R&D performance accounting for 45.3 percent of total R&D performed in OECD countries, EU performance for 26.4 percent, and Japanese performance for 18.8 percent.

## R&D Performance by Industry

The United States, the European Union, and Japan represent the three largest economies in the industrial world and compete head to head in the international marketplace. An analysis of R&D data provides some explanation for past successes in certain product markets, provides insights into future product development, and signals shifts in national technology priorities.[11]

### *United States*

R&D performance by U.S. industry followed a pattern of rapid growth during the 1970s, which accelerated during the early 1980s. That growth pattern stalled during the latter part of the decade and into the 1990s. When adjusted for inflation, U.S. industrial R&D performance shows a period of annual declines, beginning in 1992, that continued through 1994. Since then, U.S. industry has ratcheted up its performance R&D with the latest data showing annual increases of about 7 percent above inflation in both 1995 and 1996. (See figure 7-18 for the top five categories of R&D performance.)

Throughout the 1970s and 1980s, the U.S. aerospace industry was consistently the largest performer of R&D, accounting for 20–25 percent of total R&D performed by U.S. industry. The industry manufacturing electronics equipment and components was the next largest performer during this period, accounting for 11–16 percent. During the 1990s, the Nation's R&D emphasis shifted in several ways. The aerospace industry's share declined while the share for the industry manufacturing communications equipment increased. In 1996, the communications equipment industry became the top R&D performer in the United States. In many ways the more important change to emerge in the 1990s was the rise in R&D performance by U.S. service sector industries. The service sector's share of U.S. industrial R&D performance jumped from 14 percent in 1989 to 19 percent in 1990, and then rose to 24 percent in 1991 and 1992. Since 1992, the pace of R&D performance in the U.S. service sector has slowed somewhat, and R&D performance in the manufacturing sector has picked up. In 1996, manufacturing industries performed nearly 81 percent of total U.S. industrial R&D, while the share attributed to service sector industries dropped to about 19 percent.

### *Japan*

During the 1970s, R&D performance in Japanese industries grew at a higher rate than in the United States. Japanese industry continued to expand its R&D spending rapidly through 1985, more than doubling the annualized growth of the previous decade. Japanese industrial R&D spending slowed somewhat during the second half of the 1980s, but the country still led all other industrial nations in terms of average annual growth in industrial R&D. Unlike the generally declining trend observed for manufacturing industries in the United States, Japanese manufacturing industries consistently accounted for about 95 percent of all R&D performed by Japanese industry. R&D in Japanese service sector industries appears to have accelerated during the early 1990s, but that trend did not continue in 1995 and 1996. The country's industrial R&D continues to be dominated by the manufacturing sector. (See figure 7-19.)

An examination of growth trends for the top five R&D-performing industries in Japan reflects that country's long-standing emphasis on communications technology (including consumer electronics and all types of audiovisual equipment). This industry was the leading performer of R&D throughout the period reviewed. Japan's motor vehicle industry was the third leading R&D performer in 1973, but rose to number two in 1980 and has retained that position nearly every year through 1996. Japanese auto makers earned a reputation for high quality and value during these years, which earned them increasingly larger shares of the global car market.

Electrical machinery producers are also among the largest R&D performers in Japan, and they have maintained high R&D growth throughout the period examined. In 1994, this industry had moved past the motor vehicle industry to become Japan's second leading R&D-performing industry before falling back to its traditional third position in 1995 and 1996. In comparison, the U.S. electrical machinery industry's ranking among the top R&D performers in the United States has dropped steadily since 1973.

### *The European Union*

Like Japan and the United States, manufacturing industries perform the bulk of industrial R&D in the 15-nation European Union. The European Union's industrial R&D appears to be somewhat less concentrated in the mid 1990s than in the United States, but more so than in Japan. Manufactur-

[11]Industry-level data are occasionally estimated here in order to provide a complete time series for the 1973–96 period.

## Economists Estimate Rates of Return to Private R&D Investment

The study of economic returns to R&D investment has developed over the past 30 years. Although estimates of the rates of return differ, the leading researchers in the field agree that R&D has a significant and important positive effect on economic growth and the overall standard of living.

It should be noted, however, that the precise magnitude of these returns cannot be measured without the use of simplifying assumptions in the analysis. A recent survey article by Nadiri (1993) examined 63 studies in this area published by prominent economists, mostly in reference to the United States, but also in reference to Japan, Canada, France, and Germany. Looking at the results of these studies, he concluded that R&D activity renders, on average, a 20- to 30-percent annual return on private (industrial) investments. (See text table 7-2.) This is not to say that every research project has a high, or even a positive, rate of return. Rather, portfolios of scientific research projects selected for analysis have the rates of return cited above. Since they reflect average returns to a selected group of projects, these returns cannot be applied to aggregate R&D expenditures. It should also be pointed out that the more basic the research, the harder it is to evaluate the returns to R&D.

Returns to society overall are estimated to be even higher. Society often gains more from successful scientific advancements than does the organization conducting the research. Therefore, there are two rates of return: the private rate of return, which is based on the expenses incurred and profits made by the company conducting the research, and the social rate of return, which is based on the overall effects on society, including the firm conducting the research.

Recent academic research has also played a key role in enabling technological advances in the private sector. Studies show that approximately 10 percent of the new products and processes developed by firms depend on recent academic research and that the association between academic and industrial research has been strongest in medicine and electronics. (See text table 7-3.) Still, association should not be construed as causation. These studies do not rigorously establish a causal relationship between university research and industrial patents. In fact, that relationship may be reversed, to some extent, by feedback mechanisms, in which industrial patents encourage further research by local universities.

*Note:* This information was first presented in chapter 8 of *Science and Engineering Indicators 1996*.

Text table 7-2.
**Estimated annual rates of return to R&D expenditures in the United States according to various economic studies**

| Author(s) and year of study | Rate of return[a] |
|---|---|
| **Firm-level studies** | |
| Link (1983) | 3 |
| Bernstein-Nadiri (1989b) | 7 |
| Schankerman-Nadiri (1986) | 13 |
| Lichtenberg-Siegel (1991) | 13 |
| Bernstein-Nadiri (1989a) | 15 |
| Clark-Griliches (1984) | 19 |
| Griliches-Mairesse (1983) | 19 |
| Jaffe (1986) | 25 |
| Griliches (1980) | 27 |
| Mansfield (1980) | 28 |
| Griliches-Mairesse (1984) | 30 |
| Griliches-Mairesse (1986) | 33 |
| Griliches (1986) | 36 |
| Schankerman (1981) | 49 |
| Minasian (1969) | 54 |
| **Industry-level studies** | |
| Terleckyj (1980) | 0[b] |
| Griliches-Lichtenberg (1984a) | 4 |
| Patel-Soete (1988)[c] | 6 |
| Mohnen-Nadiri-Prucha (1986) | 11 |
| Terleckyj (1974) | 15 |
| Wolff-Nadiri (1987) | 15 |
| Sveikauskas (1981) | 16 |
| Bernstein-Nadiri (1988) | 19 |
| Link (1978) | 19 |
| Griliches (1980) | 21 |
| Bernstein-Nadiri (1991) | 22 |
| Scherer (1982, 1984) | 36 |

[a]For studies for which Nadiri (1993) reports a range of possible returns, the midpoint of that range is provided in this table.

[b]Not significantly different from zero in a statistical sense. This result, however, may be a reflection of limitations in the quantity of data used in the study.

[c]Economy-level study (all industries grouped together).

SOURCE: M.J. Nadiri, "Innovations and Technological Spillovers," Working Paper No. 4423 (Cambridge, MA: National Bureau of Economic Research, 1993).

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Text table 7-3.
**Percentage of new products and processes that were dependent on academic research, for selected industries in the United States: 1975–85**

| Industry | Percent dependent, at least partially, on recent academic research for their timely development | | Percent developed with "very substantial aid" from recent academic research | |
|---|---|---|---|---|
| | Products | Processes | Products | Processes |
| Information processing | 11 | 11 | 17 | 16 |
| Electronics | 6 | 3 | 3 | 4 |
| Chemical | 4 | 2 | 4 | 4 |
| Instruments | 16 | 2 | 5 | 1 |
| Pharmaceuticals | 27 | 29 | 17 | 8 |
| Metals | 13 | 12 | 9 | 9 |
| Petroleum | 1 | 1 | 1 | 1 |
| Average | 11 | 9 | 8 | 6 |

SOURCES: E. Mansfield, "Academic Research and Industrial Innovations," Research Policy 1991, 20:1–12; and E. Mansfield, "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing," *The Review of Economics and Statistics* 77(1): 55–65, 1995.

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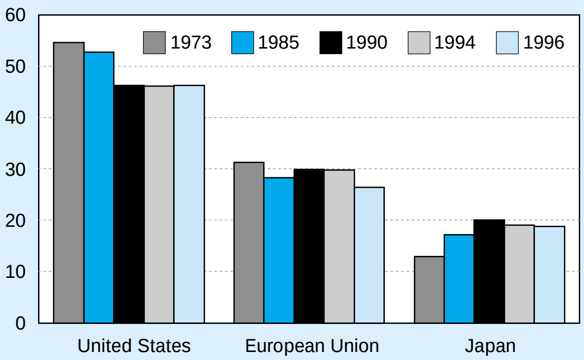
Figure 7-17.
**Shares of total industrial R&D in OECD countries**




SOURCE: The Organisation for Economic Co-operation and Development, Analytical Business Enterprise R&D database (Paris: 1997).

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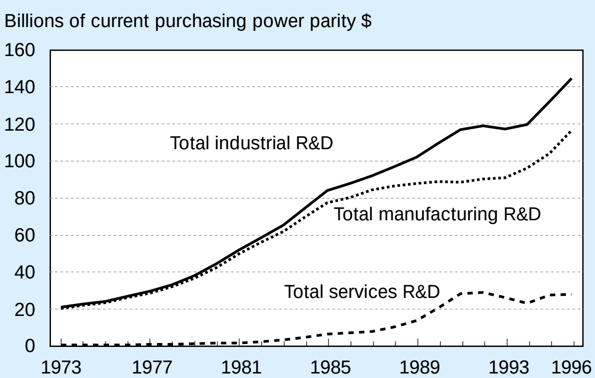
ers of electronics equipment and components, motor vehicles, and industrial chemicals have consistently been among the top five performers of industrial R&D in the European Union. (See figure 7-20.) In 1995, Germany led the European Union in the performance of motor vehicle and industrial chemical R&D, while France led in industrial R&D performed by communications equipment (consumer electronics and all types of audiovisual equipment) manufacturers, and the United Kingdom in pharmaceuticals.

R&D performed by the European Union's service sector has doubled since the mid-1980s, accounting for about 11 percent of total industrial R&D performed by 1995. Large increases in service sector R&D are apparent in many EU countries, but especially in the United Kingdom (19.6 percent of its industrial R&D in 1995), Italy (15.3 percent), and France (10.0 percent).

Figure 7-18.
**U.S. industrial R&D performance: 1973–1996**

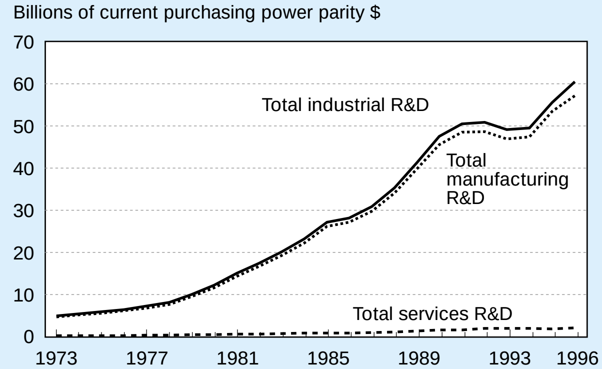



**Top industrial R&D performers and their share of total industrial R&D**

| 1976 | | 1986 | | 1996 | |
|---|---|---|---|---|---|
| Aerospace | 23.5% | Aerospace | 24.0% | Services (total) | 19.5% |
| Elec. equip. & components | 12.1% | Elec. equip. & components | 15.6% | Elec. equip. & components | 13.2% |
| Motor vehicles | 10.3% | Office machinery & computers | 11.2% | Aerospace | 11.2% |
| Office machinery & computers | 8.9% | Motor vehicles | 11.1% | Motor vehicles | 11.1% |
| Elec. machinery | 8.8% | Services (total) | 8.5% | Office machinery & computers | 8.8% |

See appendix table 7-9. *Science & Engineering Indicators – 2000*

Figure 7-19.
**Japanese industrial R&D performance: 1973–1996**

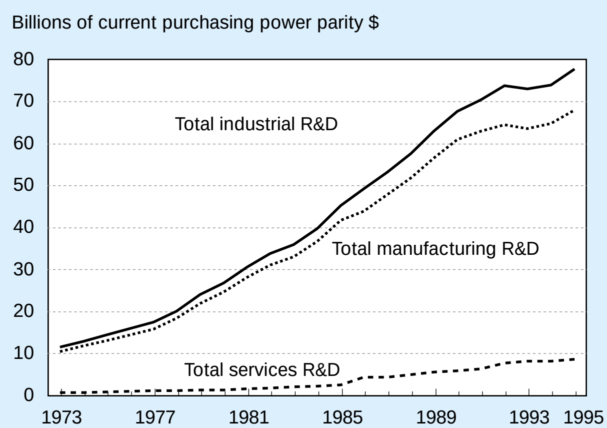



**Top industrial R&D performers and their share of total industrial R&D**

| 1976 | | 1986 | | 1996 | |
|---|---|---|---|---|---|
| Elec. equip. & components | 14.9% | Elec. equip. & components | 18.1% | Elec. equip. & components | 16.1% |
| Industrial chemicals | 12.9% | Motor vehicles | 13.1% | Motor vehicles | 12.8% |
| Motor vehicles | 11.5% | Industrial chemicals | 10.5% | Electrical machinery | 10.9% |
| Elec. machinery | 11.0% | Electrical machinery | 10.1% | Industrial chemicals | 9.2% |
| Nonelectrical machinery | 10.0% | Nonelectrical machinery | 8.3% | Nonelectrical machinery | 8.7% |

See appendix table 7-10. *Science & Engineering Indicators – 2000*

Figure 7-20.
**EU 15 industrial R&D performance: 1973–1995**




**Top industrial R&D performers and their share of total industrial R&D**

| 1976 | | 1986 | | 1995 | |
|---|---|---|---|---|---|
| Elec. equip. & components | 15.6% | Elec. equip. & components | 17.0% | Motor vehicles | 14.4% |
| Industrial chemicals | 13.3% | Industrial chemicals | 11.3% | Elec. equip. & components | 14.0% |
| Aerospace | 12.5% | Motor vehicles | 11.1% | Services (total) | 11.2% |
| Motor vehicles | 10.0% | Aerospace | 10.8% | Pharmaceuticals | 10.0% |
| Electrical machinery | 8.1% | Electrical machinery | 8.0% | Industrial chemicals | 9.6% |

NOTE: 1996 data are unavailable.

See appendix table 7-11. *Science & Engineering Indicators – 2000*

## Patented Inventions

New technical inventions have important economic benefits to a nation, because they can often lead to innovations in new or improved products or more efficient manufacturing processes—or even to new industries. To foster inventive activity, nations assign property rights to inventors in the form of patents, which allow the inventor to exclude others from making, using, or selling the invention. Inventors can obtain patents from government-authorized agencies for inventions judged to be new, useful, and nonobvious.

Patent data provide useful indicators of technical change and serve as a means of measuring inventive output over time.[12] Further, U.S. patenting by foreign inventors enables measurement of the levels of invention in those foreign countries (Pavitt 1985) and can serve as a leading indicator of new technological competition (Faust 1984). Patenting trends can therefore serve as an indicator—albeit one with certain limitations—of national inventive activities.[13]

This section describes broad trends in inventive activity in the United States over time by national origin of owner, patent office class, patent activity, and commerce activity.

### U.S. Patenting

In 1998, nearly 148,000 patents were issued in the United States. This record number of new inventions resulting in new patents capped off what had been years of increases since 1990. In 1995, U.S. patents granted fell short of the previous year's mark, but not by much. The upward trend resumed with small increases in U.S. patents granted in 1996 and 1997 before a 32 percent jump in 1998. (See appendix table 7-15.)[14]

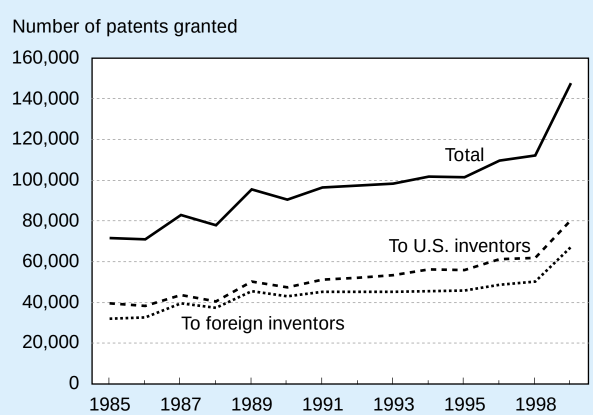
### Patents Granted to U.S. Inventors

During the 1980s, the number of U.S. patents awarded to U.S. inventors began to decline just as the number awarded to foreign inventors began to rise. This of course raised questions about U.S. inventive activity and whether these numbers were yet another indicator of U.S. competitiveness on the decline. By the end of the decade, however, U.S. inventor patenting picked up and continued to increase and outpace foreign inventor patenting in the United States. This trend has continued during the 1990s. Rising nearly every year since 1990, U.S. inventors were awarded more than 61,000 new patents in 1996 and more than 80,000 patents in 1998. (See figure 7-21.)

Inventors who work for private companies or the Federal Government commonly assign ownership of their patents to their employers; self-employed inventors typically retain ownership of their patents. Examining patent data by owner's sector of employment can therefore provide a good indication of the sector in which the inventive work was done. In 1998, 79 percent of U.S. owned patents were owned by corporations. (See the sidebar, "Top Patenting Corporations.")[15] This percentage has increased gradually over the years.[16]

After business entities, individuals are the next largest group of U.S. patent owners. Prior to 1985, individuals owned, on average, 24 percent of all U.S. owned patents.[17] Their share has fluctuated downward since then. In 1998, the share accounted for by individuals dropped to its lowest point—20 percent. The Federal share of patents averaged 3.3 percent of the total during the period 1963–84. Thereafter, U.S. Government-owned patents as a share of total U.S. origin patents declined.[18] U.S. Government-owned patents were encouraged

Figure 7-21.
**U.S. patents granted, by nationality of inventor**




See appendix table 7-12. *Science & Engineering Indicators – 2000*

[12]See Griliches (1990) for a survey of literature related to this point.

[13]Although the U.S. Patent and Trademark Office grants several types of patents, this discussion is limited to utility patents only, which are commonly known as "patents for inventions." Patenting indicators have several well-known drawbacks, including the following:

♦ *Incompleteness*—many inventions are not patented at all, in part because laws in some countries already provide for the protection of industrial trade secrets.

♦ *Inconsistency across industries and fields*—industries and fields vary considerably in their propensity to patent inventions and, consequently, it is not advisable to compare patenting rates among different industries or fields (Scherer 1992).

♦ *Inconsistency in quality*—the importance of patented inventions can vary considerably.

Despite these and other limitations, patents provide a unique source of information on inventive activities.

[14]Although patent applications have been rising, the U.S. Patent and Trademark Office attributes most of the increase in 1998 to greater administrative efficiency and the hiring of additional patent examiners.

[15]About 5 percent of U.S. patents granted to U.S. inventors in 1998 were owned by U.S. universities and colleges. The U.S. Patent and Trademark Office counts these as being owned by corporations. For further discussion of academic patenting, see chapter 6, "Academic Research and Development: Financial and Personnel Resources, Support for Graduate Education, and Outputs."

[16]From 1985 to 1995, corporate-owned patents accounted for between 73 and 76 percent of total United States–owned patents. Since then, corporations increased their share each year and represented 79 percent of total United States–owned patents in 1998.

[17]Prior to 1985, data are provided as a total for the period 1963–84.

[18]Federal inventors frequently obtain a statutory invention registration (SIR) rather than a patent. An SIR is not ordinarily subject to examination, and it costs less to obtain than a patent. Also, an SIR gives the holder the right to use the invention, but does not prevent others from selling or using it as well.

## Top Patenting Corporations

An examination of the top patenting corporations in the United States over the past 25 years illustrates the rapid technological transformation achieved by Japan during a relatively short period. In 1973, no Japanese companies were among the top 10 patenting corporations in the United States. In 1983, three Japanese companies were among the top 10. By 1993, Japanese companies outnumbered U.S. companies, and data for 1996 show 7 Japanese companies among the top 10. The most recent data (1998) now show 1 South Korean company among the top 10—3 U.S. companies, and 6 Japanese companies. (See text table 7-4.) Similar to Japan's, Korea's U.S. patenting now emphasizes computer technologies, television and communications technologies, and power generation technologies. Despite their economic problems, Korea's and Japan's continued success patenting inventions in the United States indicates a growing capacity for innovation in important technologies.

Text table 7-4.
**Top patenting corporations**

| Company | Number of patents |
|---|---|
| **In 1998** | |
| International Business Machines Corp. | 2,657 |
| Canon Kabushiki Kaisha | 1,928 |
| NEC Corporation | 1,627 |
| Motorola Inc. | 1,406 |
| Sony Corporation | 1,316 |
| Samsung Electronics Co., Ltd | 1,304 |
| Fujitsu Limited | 1,189 |
| Toshiba Corporation | 1,170 |
| Eastman Kodak Company | 1,124 |
| Hitachi, Ltd | 1,094 |
| **From 1977–96** | |
| General Electric Corp. | 16,206 |
| International Business Machines Corp. | 15,205 |
| Hitachi, Ltd | 14,500 |
| Canon Kabushiki Kaisha | 13,797 |
| Toshiba Corporation | 13,413 |
| Mitsubishi Denki Kabushiki Kaisha | 10,192 |
| U.S. Philips Corporation | 9,943 |
| Eastman Kodak Company | 9,729 |
| AT&T Corporation | 9,380 |
| Motorola Inc. | 9,143 |

SOURCE: U.S. Patent and Trademark Office, Office of Information Systems, TAF Program.

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by legislation enacted during the 1980s which called for U.S. agencies to establish new programs and increase incentives to their scientists, engineers, and technicians that would facilitate the transfer of technology developed in the course of government activities.[19]

### Patents Granted to Foreign Inventors

Foreign-origin patents represent nearly half (46 percent in 1998) of all patents granted in the United States.[20] Their share rose throughout most of the 1980s before edging downward in 1989. At their peak in 1988, foreign-origin patents accounted for 48 percent of total U.S. patents. The following year and up until 1996, U.S. inventor patenting increased at a faster pace than that by foreign inventors, dropping the foreign share to 44 percent. Both U.S. and foreign patenting picked up in 1997 and 1998.

Foreign patenting in the United States is highly concentrated by country of origin. In 1998, two countries—Japan and Germany—accounted for nearly 60 percent of U.S. patents granted to foreign inventors. The top four countries—Japan, Germany, France, and the United Kingdom—accounted for about 70 percent. (See figure 7-22.)

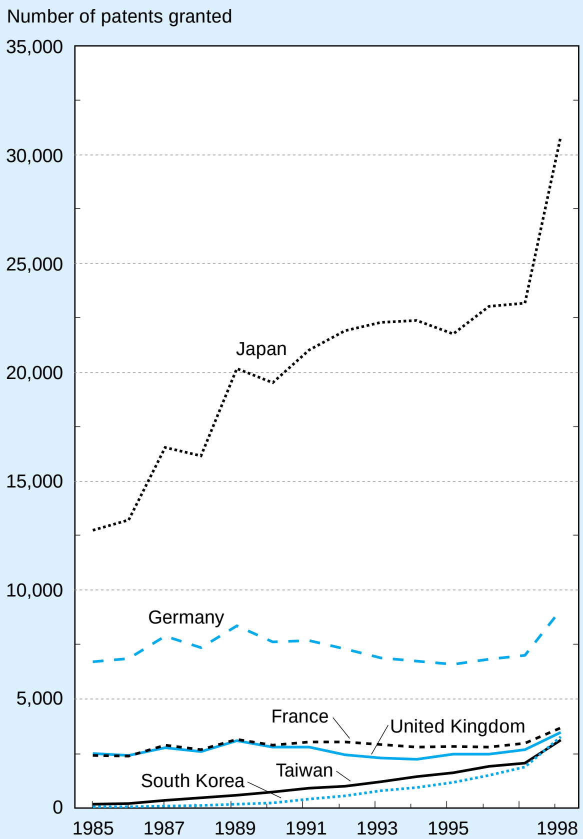
While patenting by inventors from the leading industrial countries has leveled off and has even begun to decline in some instances other economies, particularly Asian economies outside Japan, have stepped up their patenting activity in the United States and are showing themselves to be strong inventors of new technologies.[21] This is especially true for Taiwan and South Korea. Before 1985 (data are available starting in 1963), Taiwan was awarded just 568 U.S. patents. Between 1985 and 1995, Taiwan was awarded nearly 9,000 U.S. patents. During the next three years, Taiwan was awarded another 7,000 U.S. patents. U.S. patenting activity by inventors from South Korea shows a similar growth pattern. Before 1985, South Korea was awarded just 172 U.S. patents. Since then, more than 11,000 new patents have been awarded. In 1998, South Korea was awarded more patents than Taiwan, and both countries surpassed Canada to become the fifth and sixth most active foreigner inventors in the United States. Sweden and the Netherlands are two other countries awarded more than 1,000 patents and showing large increases in U.S. patenting in 1998.

[19]The Stevenson-Wydler Technology Innovation Act of 1980 made the transfer of federally owned or originated technology to state and local governments and to the private sector a national policy and the duty of government laboratories. The act was amended by the Federal Technology Transfer Act of 1986 to provide additional incentives for the transfer and commercialization of federally developed technologies. Later, Executive Order 12591 of April 1987 ordered executive departments and agencies to encourage and facilitate collaborations among federal laboratories, state and local governments, universities, and the private sector—particularly small business—to aid technology transfer to the marketplace. In 1996, Congress strengthened private sector rights to intellectual property resulting from these partnerships.

[20]Corporations account for about 90 percent of all foreign-owned U.S. patents in 1998.

[21]Some of the decline in U.S. patenting by inventors from the leading industrial nations may be attributed to the move toward European unification, which has encouraged wider patenting within Europe.

Figure 7-22.
**U.S. patents granted to foreign inventors, by nationality of inventor**




NOTE: Selected countries are the top six recipients of U.S. patents during 1998.

See appendix table 7-12. *Science & Engineering Indicators – 2000*

## Technical Fields Favored by Foreign Inventors

A country's distribution of patents by technical area has proved to be a reliable indicator of a nation's technological strengths, as well as an indicator of direction in product development. This section compares and discusses the various key technical fields favored by inventors in the world's three leading economies—the United States, Japan, and Germany—and in two newly industrialized economies—Taiwan and South Korea.[22]

### *Fields Favored by U.S., Japanese, and German Inventors*

While U.S. patent activity spans a wide spectrum of technology and new product areas, the patenting of U.S. corporations shows a particular emphasis on several of the technology areas that are expected to play an important role in future economic growth. (See U.S. OSTP 1997, pp. 5–9.) In 1997, corporate patent activity reflected U.S. technological strengths in developing new medical and surgical devices, electronics, telecommunications, advanced materials, and biotechnology. (See text table 7-5.)

The 1997 patent data continue to show Japanese inventors emphasizing technology classes associated with photography, office machines, and consumer electronics industries. What is also evident in 1997 is the broader range of U.S. patents awarded to Japanese inventors in information technology. From improved information storage technology for computers to visual display systems, Japanese inventions are earning U.S. patents in areas that aid the processing, storage, and transmission of information.

German inventors continue to develop new products and processes in technology areas associated with heavy manufacturing industries in which that country has traditionally maintained a strong presence. The 1997 U.S. patent activity index shows a German emphasis on motor vehicles, printing, new chemistry and advanced materials, and material handling equipment-related patent classes.

### *Fields Favored by Two Newly Industrialized Economies*

Patent activity in the United States by inventors from foreign countries can be used to identify a country's technological strengths and is also seen as a leading indicator of U.S. product markets likely to see increased competition.

As recently as 1980, Taiwan's U.S. patent activity was primarily in the area of toys and other amusement devices. By the 1990s, Taiwan was active in such areas as communications technology, semiconductor manufacturing processes, and internal combustion engines. The latest available data (1997) show that inventors from Taiwan have continued to patent heavily in processes used in the manufacture of semiconductor devices. They also show heavy activity in computer storage and display devices, advanced materials, and transistors. (See text table 7-6.) Ten years earlier, inventors from Taiwan received only 1 patent in any of these technology classes.

U.S. patenting by South Korean inventors has also shown rapid technological development. The 1997 data show that Korean inventors are patenting heavily in television technologies and a broad array of computer technologies that include devices for dynamic and static information storage, data generation and conversion, error detection, and display systems. (See text table 7-6.)

Both South Korea and Taiwan are already major suppliers of computers and peripherals to the United States. The recent patenting data show that their scientists and engineers are

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[22]Information in this section is based on the U.S. Patent and Trademark Office's classification system, which divides patents into approximately 370 active classes. With this system, patent activity for U.S. and foreign inventors in recent years can be compared by developing an activity index. For any year, the activity index is the proportion of patents in a particular class granted to inventors in a specific country divided by the proportion of all patents granted to inventors in that country. Because U.S. patenting data reflect a much larger share of patenting by individuals without corporate or government affiliation than do data on foreign patenting, only patents granted to corporations are used to construct the U.S. patenting activity indices.

continuing to develop the new technologies and improve existing technologies. It is likely that these new inventions will enhance their competitiveness in the United States and global markets.

### Patenting Outside the United States

In most parts of the world, foreign inventors account for a much larger share of total patent activity than is the case in the United States. When foreign patent activity in the United States is compared with that in 11 other important countries in 1985, 1990, and again in 1996, only Russia and Japan had less foreign patent activity. (See figure 7-23 and appendix table 7-13.)

What is often obscured by the rising numbers in foreign-origin patents in the United States is the success and widespread activity of U.S. inventors in patenting their inventions around the world. In 1996, U.S. inventors led all other foreign inventors not just in countries neighboring the United States, but also in distant and diverse markets, such as Japan, France, Italy, Brazil, India, Malaysia, and Thailand. (See figure 7-24.) Japanese inventors edge out Americans in Germany and dominate foreign patenting in South Korea. German inventors lead all foreign inventors in Russia; they are also quite active in many of the other countries examined.

## Venture Capital and High-Technology Enterprise

One of the most serious challenges to new entrepreneurs in the innovation process is capital—or the lack thereof. Venture capitalists typically make investments in small, young companies that may not have access to public or credit-oriented institutional funding. Venture capital investments can be long term and high risk, and may include hands-on involvement by the venture capitalist in the firm. Venture capital thus can aid the growth of promising small companies and facilitate the introduction of new products and technologies, and is an important source of funds used in the formation and expansion of small high-technology companies. This section examines investments made by U.S. venture capital firms, by stage of financing and by technology area.

The pool of capital managed by venture capital firms grew dramatically during the 1980s as venture capital emerged as a truly important source of financing for small innovative firms. (See text table 7-7.) By 1989, the capital managed by venture capital firms totaled $33.5 billion, up from an estimated $4.1 billion in 1980. The number of venture capital firms also grew during the 1980s—from around 448 in 1983 to 670 in 1989.

In the early 1990s, the venture capital industry experienced

Text table 7-5.
**Top 15 most emphasized U.S. patent classes for corporations from the United States, Japan, and Germany: 1997**

| United States | Japan | Germany |
|---|---|---|
| 1. Surgical Instruments | Photography | Printing |
| 2. Biology of multicellular organisms | Information storage and retrieval | Plant protecting and regulating compositions |
| 3. Surgery: light, thermal, and electrical applications | Electrophotography | Clutches and power-stop control |
| 4. Surgery: application, storage, and collection | Liquid crystal cells | X-ray or gamma ray devices |
| 5. Prothesis | Facsimile | Organic compounds (includes classes 532–570) |
| 6. Computers and digital processing | Typewriting machines | Fabrication of plastics and earthenware |
| 7. Data processing | Television signal processing | Machine element or mechanism |
| 8. Special receptacle or package | Printing of symbolic information | Winding, tensioning, or guiding devices |
| 9. Telephone communications | Optics: systems and element | Metal deforming |
| 10. Communications: Directive radio wave systems | Active solid-state devices | Internal combustion engines |
| 11. Chemistry: Molecular biology and microbiology | Radiation imagery chemistry | Coating or plastic fabrication |
| 12. Chemistry: Natural resins or derivatives | Storage or retrieval of magnetic information | Paper making |
| 13. Information processing system organization | Internal-combustion engines | Power-driven conveyors |
| 14. Cryptography | Television | Sheet feeding or delivering |
| 15. Chemistry: analytical and immunological testing | Electrical generator or motors | Synthetic resins or natural rubbers |

NOTE: Ranking is based on patenting activity of nongovernment U.S. or foreign organizations, which are predominantly corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Information Systems, TAF Program.

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Text table 7-6.
**Top 15 most emphasized U.S. patent classes for corporations from South Korea and Taiwan: 1997**

| South Korea | Taiwan |
|---|---|
| 1. Television signal processing for recording | Semiconductor device manufacturing process |
| 2. Television | Etching substrate processes |
| 3. Static information storage and retrieval | Solid state devices |
| 4. Semiconductor manufacturing process | Metal treatment |
| 5. Electric lamp and discharge devices | Coded data generation or conversion |
| 6. Dynamic information storage or retrieval | Electrical nonlinear devices |
| 7. Dynamic magnetic information storage or retrieval | Illumination |
| 8. Coded data generation or conversion | Electrical connectors |
| 9. Electric heating | Supports |
| 10. Refrigeration | Fluid sprinkling, spraying, and diffusing |
| 11. Electric lamp and discharge devices | Receptacles |
| 12. Miscellaneous active electrical nonlinear devices | Audio processing systems and devices |
| 13. Liquid crystal cells, elements and systems | Computer graphics processing |
| 14. Winding, tensioning, or guiding | Static information storage and retrieval |
| 15. Electrical power supply or regulation systems | Electronic digital logic circuitry |

NOTE: Ranking is based on patenting activity of nongovernmental organizations, which are primarily corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Information Systems, TAF Program.

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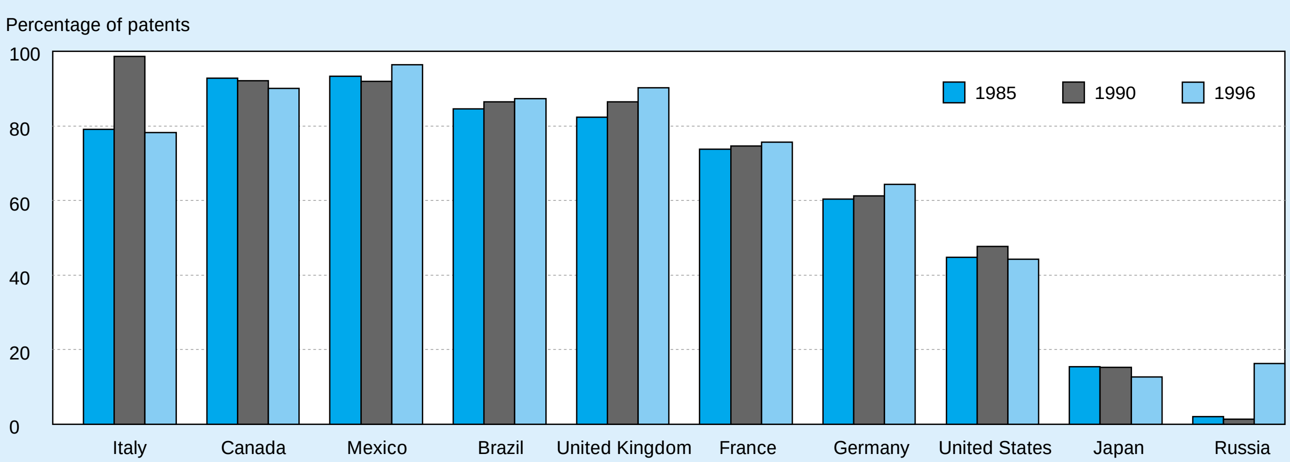
a recession of sorts, as investor interest waned and the amount of venture capital disbursed to companies declined—especially compared to the extensive venture capital activity of the late 1980s. The number of firms managing venture capital also declined during the early 1990s, but the slowdown was short-lived. Investor interest picked up during 1992, and disbursements began to rise. Both investor interest and venture capital disbursements have continued to grow through 1998. The latest data show that total venture capital under management rose to $84.2 billion in 1998, more than double the amount managed just three years earlier.

California, New York, and Massachusetts together account for about 65 percent of venture capital resources. It appears that venture capital firms tend to cluster around locales considered to be "hotbeds" of technological activity, as well as in states where large amounts of R&D are performed.[23]

[23]Discussion on the location of venture capital firms is derived from data presented in Venture Economics Information Services (1999). Data on U.S. R&D performance by state are presented in chapter 4, "Higher Education in Science and Engineering."

Figure 7-23.
**Share of total patents awarded to nonresident inventors**




See appendix tables 7-12 and 7-13.

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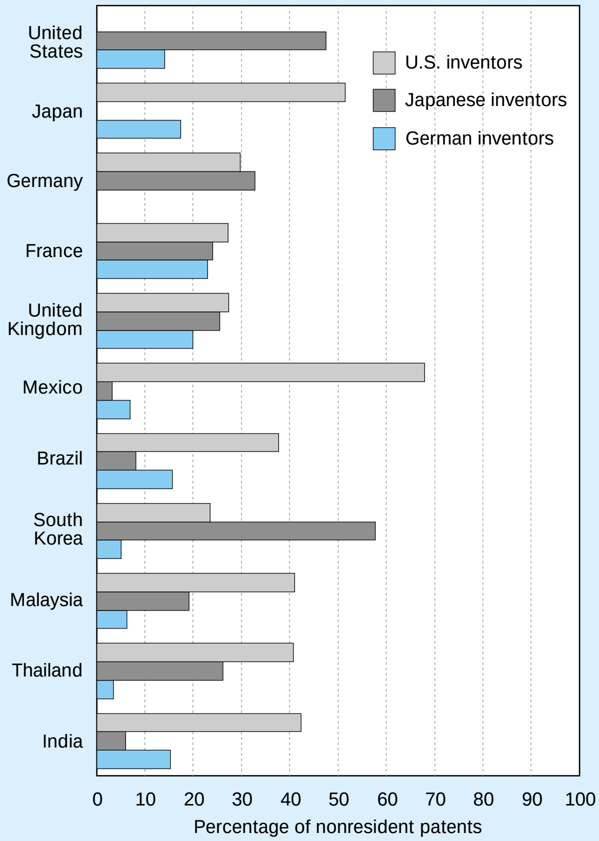
Figure 7-24.
**Patents granted to nonresident inventors: 1996**




NOTE: Data for Malaysia and Thailand taken directly from source documents.

See appendix table 7-13. *Science & Engineering Indicators – 2000*

Text table 7-7.
**Venture capital under management in the United States: 1980–98**
(Millions of U.S. dollars)

| | New capital committed | Total venture capital under management |
|---|---|---|
| 1980 | 2,073.6 | 4,071.1 |
| 1981 | 1,133.2 | 5,685.7 |
| 1982 | 1,546.4 | 7,758.7 |
| 1983 | 4,120.4 | 12,201.2 |
| 1984 | 3,048.5 | 15,759.3 |
| 1985 | 3,040.0 | 19,330.6 |
| 1986 | 3,613.1 | 23,371.4 |
| 1987 | 4,023.9 | 26,998.5 |
| 1988 | 3,491.9 | 29,539.2 |
| 1989 | 5,197.6 | 33,466.9 |
| 1990 | 2,550.4 | 34,000.9 |
| 1991 | 1,488.0 | 31,587.2 |
| 1992 | 3,392.8 | 30,557.3 |
| 1993 | 4,115.3 | 31,894.0 |
| 1994 | 7,339.4 | 34,841.3 |
| 1995 | 8,426.7 | 38,465.0 |
| 1996 | 10,467.2 | 46,207.2 |
| 1997 | 15,175.6 | 59,614.5 |
| 1998 | 25,292.6 | 84,180.1 |

SOURCE: 1999 National Venture Capital Association Yearbook, Venture Economics Information Services (1999).

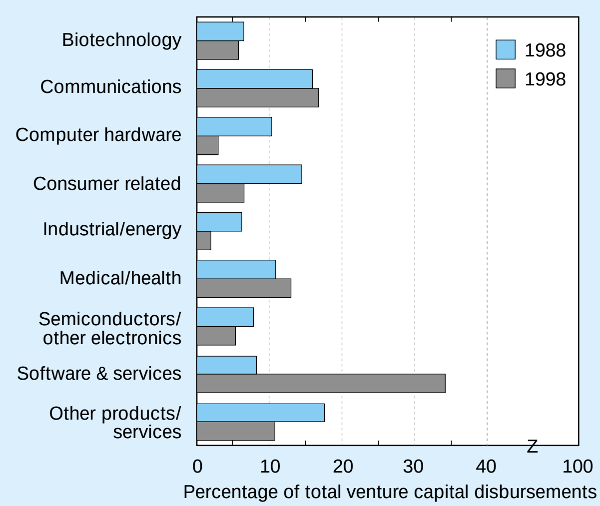
*Science & Engineering Indicators – 2000*

## Venture Capital Commitments and Disbursements

Several years of very high returns on venture capital investments have stimulated increased investor interest. This interest soared from 1995 to 1998, with new commitments reaching $25.3 billion in 1998, up from $15.2 billion in 1997, and $10.5 billion in 1996. Pension funds remain the single largest supplier of new funds, supplying nearly 60 percent of committed capital in 1998. Corporations are the next largest source, supplying 12 percent of committed capital, followed closely by individuals at 11 percent.[24]

Starting in 1994, new capital raised exceeded capital disbursed by the venture capital industry. In each of the following years, that gap has grown larger and larger, creating surplus funds available for investments in new or expanding innovative firms. Since 1990, firms producing computer software or providing computer-related services generally received the largest share of new disbursements. (See figure 7-25 and appendix table 7-14.) In 1990, software companies received 17 percent of all new venture capital disbursements, twice the share going to computer hardware companies and biotechnology companies. That share rose to 27 percent in 1993, and again in 1997. The latest data show software companies receiving more than one-third of all venture capital disbursements in 1998. Telecommunications companies also attracted

Figure 7-25.
**U.S. venture capital disbursements, by industry category: 1988 and 1998**




See appendix table 7-14. *Science & Engineering Indicators – 2000*

[24]Based on information contained in Venture Economics Information Services (1999).

large amounts of venture capital during the 1990s, and edged out software companies for the lead in 1992 and 1994. Medical and health-care related companies received a large share of venture capital throughout the 1990s, reaching a high of 18 percent in 1994 before dropping to 14 percent in 1998. Computer hardware companies, an industry highly favored by the venture capitalists during the 1980s, received just 3 percent of total venture capital disbursements in the most recent period.

## Venture Capital Investments by Stage of Financing

The investments made by venture capital firms may be categorized by the stage at which the financing is provided:[24]

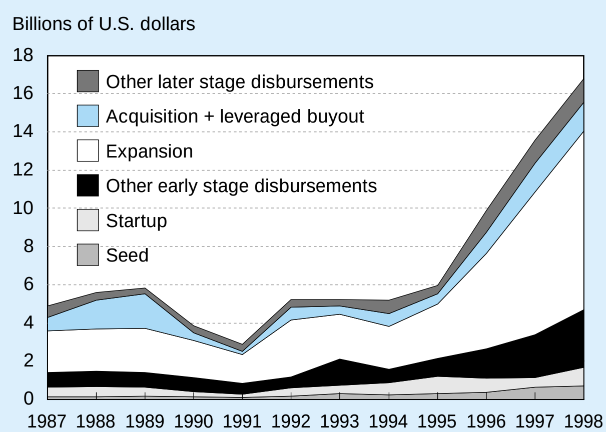
- *Seed financing*—usually involves a small amount of capital provided to an inventor or entrepreneur to prove a concept. It may support product development, but rarely is used for marketing.
- *Startup financing*—provides funds to companies for use in product development and initial marketing. This type of financing usually is provided to companies that are just getting organized or to those that have been in business just a short time, but have not yet sold their products in the marketplace. Generally, such firms have already assembled key management, prepared a business plan, and made market studies.
- *First-stage financing*—provides funds to companies that have exhausted their initial capital and that need funds to initiate commercial manufacturing and sales.
- *Expansion financing*—includes working capital for the initial expansion of a company, funds for either major growth expansion (involving plant expansion, marketing, or development of an improved product development), and financing for a company expecting to go public within six months to a year.
- *Acquisition financing*—provides funds to finance the purchase of another company.[25]
- *Management and leveraged buyout*— includes funds to enable operating management to acquire a product line or business from either a public or private company. Often these companies are closely held or family owned.[26]

For this report, the first three are referred to as early-stage financing and the remaining three as later-stage financing.

An examination of venture capital disbursements by financing stage clearly shows that most of the funds are directed to later-stage investments. Since 1982, later-stage investments captured between 59 and 75 percent of venture capital disbursements, with the high and low points both reached in the 1990s. In 1998, later-stage investments represented 72 percent of total disbursements. (See figure 7-26 and appendix table 7-15.) Capital for company expansions attracted by far the most investor interest with this financing stage alone attracting more than half of all venture capital disbursed since 1995.

Contrary to how venture capital is often viewed, only a relatively small amount of venture capital goes to the struggling inventor or entrepreneur trying to prove a concept or to help with product development. Over the 19-year period examined, such seed money never accounted for more than 6 percent of all venture capital disbursements, and most often represented between 2 and 4 percent of the annual totals. Seed financing represented about 5 percent of all venture capital in four of the last five years. Consistent with observations made when all venture capital investments are examined, firms developing computer software, telecommunications technologies, and those classified as medical and health-related are the largest recipients of venture capital seed-type financing in the late 1990s. (See appendix table 7-16.) Computer software is the leading technology area receiving seed-type financing, although its share is slightly lower than that seen in the examination of total venture capital investments (34 percent overall versus 32 percent as seed money). Recently, telecommunications firms gained favor with forward-looking venture capitalists and attracted 21 percent of venture capital seed-stage investments in 1998, up from 15 percent in 1997, and 7 percent in 1996. Medical and health-related firms received about 20 percent in each of the last two years examined.

Figure 7-26.
**U.S. venture capital disbursements, by stage of financing: 1987–98**




See appendix table 7-15. *Science & Engineering Indicators – 2000*

## Summary: Assessment of U.S. Technological Competitiveness

This chapter brings together a collection of indicators that contrast and compare national technological competitiveness across a broad range of important technological areas. Based on the various indicators of technology development and market competitiveness examined, the United States continues to lead or be among the leaders in all major technology areas. Advancements in information technologies (computers and telecommunications products) continue to influence new technology development and to dominate technical exchanges between the United States and its trading partners.

Asia's status as both a consumer and developer of high-technology products has been enhanced by the technological development taking place in the newly industrialized Asian economies—in particular, South Korea and Taiwan—and in emerging and transitioning economies, such as China, Malaysia, and the Philippines. Based on the trends presented in this chapter in patenting, in high-technology production, and purchases of technological know-how, Asia's influence in the marketplace seems likely to expand in the future as other technologically emerging Asian nations join Japan as both technology producers and consumers.

The current strong position of the United States as the world's leading producer of high-technology products reflects its success both in supplying a large home-based market, as well as in serving foreign markets. In addition to the Nation's long commitment to investments in S&T, this success in the international marketplace may in part be a function of scale effects derived from serving this large, demanding domestic market. It may be further aided by the U.S. market's openness to foreign competition. In the years ahead, these same market dynamics may also benefit a more unified Europe and Latin America and a rapidly developing Asia and complement their investments in S&T.

Beyond these challenges, the rapid technological development taking place around the world also offers new opportunities for the U.S. S&T enterprise. For U.S. business, rising exports of high-technology products and services to expanding economies in Asia, Europe, and Latin America are already apparent in the U.S. trade data and should grow in the years ahead. For research, the same conditions that create new business opportunities—the growing global technological capacity and the relaxation of restrictions on international business—can lead to new opportunities for the U.S. S&T research community. The many new, well-funded institutes and technology-oriented universities surfacing in many technologically emerging areas of the world will further scientific and technological knowledge and lead to new collaborations between U.S. and foreign researchers.

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